Mathematics and statistics related studies in Indonesia using co-authorship network analysis
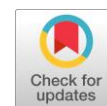
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ARTICLE INFO

ABSTRACT

Indonesian scholars have published a numbers of articles in numerous international publications, however, it still lags behind other Singapore, Malaysia and Vietnam. This article performs a bibliometrics analysis and examine the collaboration network in Mathematics and Statistics related subject of scholars with Indonesian affiliation as recorded in Web of Science. In total, based on article publications during 2009-2017, 426 articles were retrieved. Bandung Institute of Technology (ITB) was the affiliation with the highest number of articles (48%) and number of authors (27%). Using Social Network Analysis to examine co-authorship networks, this research shows that the co-author network has the highest centrality in the ITB affiliation. Meanwhile, dependency of foreign affiliation is still high, shown as a high percentage (84% of all articles) of international co-authorship. Co-authorship network of Mathematics and Statistics related studies in Indonesia possesses as a scale-free network and followed the power law distribution. This research showed the achievement of Indonesian scholars of Mathematics and Statistics, and can be used to evaluate the knowledge transfer in these subjects and related areas.

1. Introduction

As the fourth most populous country in the world, Indonesia has great potential because around 43% of its 250 million people are young or under 25 years old [1] and participation in formal education (higher education level) in 2017 increased 113.78% compared to 2005 [2]. Indonesian scholars also have published a numbers of articles in numerous international journal, but in fact, it still lacking in publications compared with other ASEAN countries such as Singapore, Malaysia, and Vietnam. Bibliometrics studies can identify and measure the contribution of Indonesian scholars to the advancement of knowledge [3]. Bibliometric research can be used to advance knowledge of science and technology development in relation to social and policy issues [4]. Some of these are citation analysis for assessment of research performance and co-word analysis for mapping science and producing visualization of field of science [5]. Several bibliometrics and scientometrics research carried out in Mathematics and related areas. For example, Arunachalam [6] described mathematics research in India, and Asadi [3] explored the research trend in information theory using a bibliometrics approach. Bibliometrics and Scientometrics approaches are used in a large body of research in order to measure the productivity of scholars in a subject area at a country or international level. Nadhiroh et al. [7] conducted a scientometric study using social network analysis methods to explore central actors and institutions involved in Indonesia scientific publication in Chemistry.

Arunachalam [6], Van Raan [5], and Asadi [3] in their studies only discussed research trends using bibliometric analysis. The study using SNA has been done by Nadhiroh et al. [7] in chemistry but only

discuss about co-authorship. Although this study also uses SNA but rather explores the co-authorship and research trend based on keyword in different area of mathematics and statistics subjects.

This article carry out a social network analysis and examine the collaboration network, in Mathematics and Statistics related subjects, of scholars, with Indonesian affiliation, as recorded in the Thomson Reuters Web of Science database. This research focuses on the number and growth rate of articles in the Mathematics and Statistics, universities and institution with the greatest number of articles, and the most productive and effective author, authorship and collaboration pattern, and the research trend based on keywords that commonly occurred in the articles.

2. Method

This research uses Thomson Reuters Web of Science database using the following search strategy: "Indonesia" in address of affiliation; "Mathematics" or "Statistics" in research area of the articles. The time span limited to 2009-2017, the data was accessed May 13th, 2018. The Thomson Reuters Web of Science database was selected, and according to Wen & Huang [8], it is the most widely accepted and frequently used database for analysis of scientific publications. This research analyzed scholars who have affiliation located in Indonesia, and included non-Indonesian scholars, with an affiliation address in Indonesia, were included in the analysis.

The analysis has the two sections. First, descriptive data related to the number of authors and the number of articles, performance of authors and institutions, research areas of Indonesian affiliation and the journals used. Second, the collaboration/co-authorship patterns and research trend of Indonesian affiliated scholars in Mathematics/Statistics related studies. Using the metrics of Social Network Analysis (SNA), this research examined the co-authorship network at both author and affiliation levels. Ucinet, Netdraw, and VosViewer software were used in this research to visualize co-authorship networks.

3. Results and Discussion

3.1. Descriptive Data

In total, 426 publications were retrieved. Duplicate records were excluded; 690 authors from 306 institutions. Table 1 shows the yearly distribution of publications production and the number of authors in mathematics or statistics area of study with Indonesian affiliation.

Table 1. Number of articles and authors in Mathematics/Statistics scientific publication of authors with Indonesian affiliation

Year	Number of Publications	Number of Authors	Ratio (Author/Articles)
2009	19	54	2.84
2010	20	65	3.25
2011	24	68	2.83
2012	19	51	2.68
2013	36	107	2.97
2014	36	112	3.11
2015	130	436	3.35
2016	64	209	3.27
2017	78	293	3.76

The number of authors grew significantly (110%) in 2013 then grew even higher in 2015 (283%) but with a decline back to the average growth rate of publications and authors (Fig. 1). Bandung Institute of Technology (ITB) was the affiliation with the highest number of publications and number of authors. The second and third affiliation with the highest number of publications are Gadjah Mada University (UGM) and Sepuluh November Institute of Technology. Even though, number of authors of UGM is less than number of authors of Sepuluh November Institute of Technology (Table 2).
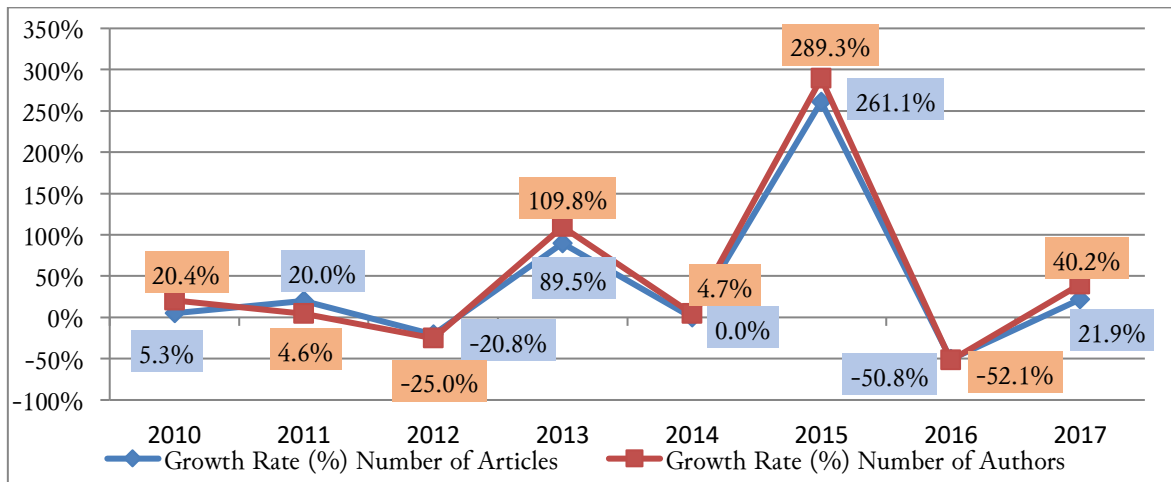
Fig. 1. Growth rate of number of articles and authors

Table 2 shows the number of author and articles from ITB are much higher than other institutions, 18.3% from total number of authors and 32.4% from total number of articles, and therefore the highest author/article ratio of 1.85. ITB was the first university with a mathematics faculty in Indonesia and may have affected the quality of human resource and network connection of scholars.

Table 2. Number of authors and articles by affiliation (The Big 10), year 2009-2017

No	Affiliation Name	Number of Authors	%	Number of Publications	%	Ratio (Authors/ Publications)
1	Bandung Institute of Technology (ITB)	255	18.3	138	32.4	1.85
2	Sepuluh November Institute of Technology (ITS)	102	7.3	41	9.6	2.49
3	Gadjah Mada University (UGM)	95	6.8	50	11.7	1.90
4	Bogor Agricultural University (IPB)	51	3.7	25	5.9	2.04
5	University of Indonesia (UI)	27	1.9	14	3.3	1.93
6	Hasanuddin University	26	1.6	19	4.5	1.37
7	Bina Nusantara University	20	1.4	10	2.3	2.00
8	Jember University	19	1.4	10	2.3	1.90
9	University Kebangsaan Malaysia	18	1.3	10	2.3	1.80
10	Brawijaya University	18	1.3	11	2.6	1.64

Table 3 shows the domination of ITB in the international publication of mathematics and statistics related area in Indonesia. Eight of the top 10 authors are from ITB. Edy T Baskoro (ITB) is author with the highest number of articles (30), followed by his ITB colleagues ANM Salman (15).

Table 3. Top 10 number of articles by Indonesian affiliation scholars, year 2009-2017

No	Scholars Name	Affiliation	Number of Articles	%
1	Baskoro, E. T.	ITB	30	7
2	Salman, A. N. M	ITB	15	3.5
3	Wijayanti, Indah Emilia	UGM	14	3.3
4	Miller, Minka	ITB	14	3.3
5	Gunawan, Hendra	ITB	13	3.1
6	Bahri, Mawardi	Hasanuddin University	11	2.6
7	Pudjaprasetya, S. R.	ITB	10	2.3
8	Astuti, Pudji	ITB	10	2.3
9	Assiyatun, Hilda	ITB	10	2.3
10	Soewono, Edy	ITB	8	1.9

Research area variables in Thomson Reuters Web of Sciences are article based, and indicate the subject area of each article. Table 4 shows that most articles in Mathematics and Statistics publications related studies had mathematics (77%) as the key research area with Computer Science (3%), Engineering (5%) and Physics (2%) as the most common related research areas in mathematics/statistics articles published by Indonesian affiliation scholars.

Table 4. Research area of Indonesian affiliation scholars articles in Mathematics and Statistics related are of studies, year 2009-2017

No	Research Area	Number of Articles	%
1	Mathematics	328	77
2	Computer Science; Mathematics	13	3
3	Engineering; Mathematics	11	3
4	Engineering; Mathematics; Mechanics	10	2
5	Mathematics; Physics	7	2
6	Mathematics; Science & Technology -Other Topics	5	1
7	Engineering; Operations Research & Management Science; Mathematics	5	1
8	Mathematics; Mechanics	3	1
9	Automation & Control Systems; Operations Research & Management Science; Mathematics	3	1
10	Operations Research & Management Science; Mathematics	3	1

Table 5 shows that 12% of all articles in the Mathematics and Statistics studies area, by Indonesian affiliation scholars, were published in International Journal of Applied Mathematics 7 Statistics (19%) and JP Journal of Algebra Number Theory and Applications (3%).

Table 5. Journals used by Indonesian affiliation scholars to publish two or more articles in Mathematics and Statistics related area of studies, year 2009-2017

No	Journal	Number of Articles	%
1	International Journal 0f Applied Mathematics & Statistics	82	19
2	JP Journal of Algebra Number Theory and Applications	14	3
3	Utilitas Mathematica	13	3
4	Applied Mathematics and Computation	10	2
5	Discrete Mathematics	10	2
6	Applied Mathematical Modelling	9	2
7	East Asian Journal on Applied Mathematics	9	2
8	Journal of the Indonesian Mathematical Society	8	2
9	Malaysian Journal of Mathematical Sciences	8	2
10	Ars Combinatoria	8	2

3.2. Collaboration Network

The average ratio of authors by article during 2009-2017, is 3.1 (Table 1), meaning that there were, on average, three authors of every article. Only 40 articles (9%) have one author, the rest are articles with multiple authors. on the other hand, 84% (359) of all articles produced are by collaboration works between Indonesian affiliation scholars and non-Indonesian scholars. Only 16% (67) articles were produced by Indonesian affiliation scholars without international collaboration which showed the high dependency of Indonesian affiliation scholars on foreign scholars to publish their work in international

journals. Percentage of collaboration articles increased in the past five years parallel with the increase of number of articles (Fig. 2).

A deep comprehension of the dynamics of scientific collaboration in Mathematics and Statistics related studies of Indonesian affiliation scholars can be carried out using Social Network Analysis. This analysis will portray the links of each scholar and the relative adjacency of other scholars. Abbasi and Altmann [9] conclude that using SNA can help people understand how to share the knowledge via the social network and evaluate the performance in the individual, group, or entire networks. The node of the graph represents the actor, whereas, in this study, node represents the author [10]. In this article, edge is the co-authorship relationship between the authors in these studies.
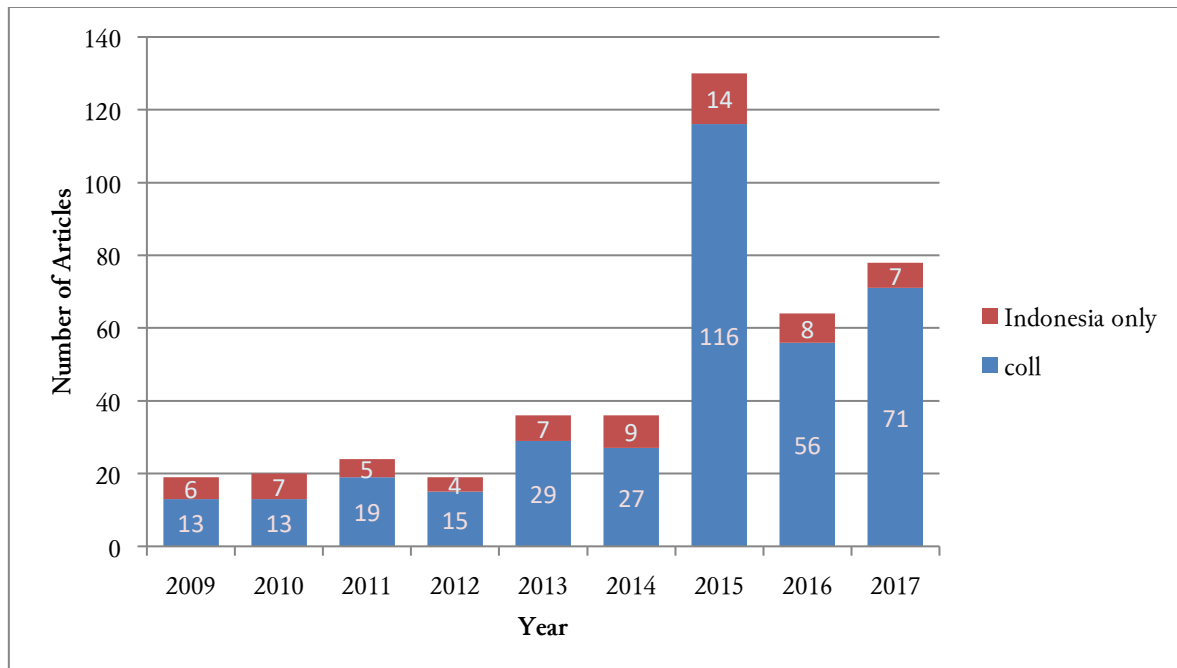

Fig. 2. Distribution of articles produced by collaboration works between Indonesian affiliation scholars and foreign affiliation scholars

SNA has been widely used to explore the co-authorship network in scientific publications at both country and/or area level. For example, Glanzel & Schubert [11] analyzed scientific networks through co-authorship. Mena-Chalco et al. [12] studied the co-authorship network in Brazil. Alhaider et al. [13] studied the co-authorship network in the Pharmacy area in United Arab Emirate. Sorensen et al. [14] studied the co-authorship network in the research of Alzheimer disease. Li & Li [15] examined the pattern and evolution of co-authorship in China's humanities and social sciences. Yan et al. [16] mapped co-authorship networks in library and information science in China.

SNA metrics measure different levels within a network. Macro-level metrics used to identify the global character of the network [16] and micro-metrics that measure sub-networks of such as individuals (e.g. journals or scholars) and groups (e.g. scholars within a specific institution or a specific group of scholars within an institution). Table 6 shows the network description of co-authorship network of Indonesian affiliation scholars in three networks: all authors in the network, ITB network as a subset of all authors and a network of a big cluster of ITB authors. Network description uses metrics such as network density (ND), degree centrality (DC), closeness centrality (CC) and betweenness centrality (BC). The mean degree centrality reflects the average number of authors that have co-authors in the network.

The Network Density (ND) describes the portion of the potential connection in a network that are actual connections. A potential connection is a connection that could potentially exist between two nodes-regardless of whether or not it actually does. By contrast, an actual connection is one that exists. The network density of all authors is 0.7%, the analysis showed that the total number of potential

connections between these authors is 475,410. Of those potential connections, there are only 3,084 actual connections, therefore the network density was 0.7%. The network density of ITB sub-network was 2% and the big cluster of ITB network was 5.4%.

The mean Degree Centrality (DC) of the 3 networks was 5 or 4, which means that co-authorship of Mathematics and Statistics related studies of Indonesian affiliation scholars is very low. As a comparison, this result is quite similar with Grossman [17] and Newman [18] found, the average number of co-authors in the co-authorship network of *Mathematical Review Journal* during 1940-2009, had a DC 2.9 or 3 co-authors per each author. Meanwhile, Brunson et al. [19] examined the co-authorship network of *Mathematical Review Journal* during 1985-2009 and they found the mean number of co-authors in the co-authorship network had a DC of 4.1. The standard deviation of DC reflects the variation in the number of authors that have co-authors in the network.

Table 6. Network statistics descriptive for three co-authorship networks of Indonesian affiliation scholars in Mathematics and Statistics related studies

Network Description	All Author	ITB network	Big cluster of ITB's
Number of Authors	690	210	98
Number of ties	3084	858	510
Degree Centrality (DC)			
Mean of DC	5	4	5
Minimum of DC	1	1	1
Maximum of DC	79	47	47
Standard deviation of DC	5	5	6
Closeness Centrality (CC)			
Mean of CC	442	1512	280
Minimum of CC	1	1082	162
Maximum of CC	2485	1873	456
Standard deviation of CC	572	301	53
Betweenness Centrality (BC)			
Mean of BC	1	70	91
Minimum of BC	0	0	0
Maximum of BC	10	3173	2300
Standard deviation of BC	3	326	333
Network Density	*0.7%*	*2.0%*	*5.4%*

The Closeness Centrality metric (CC) is based on the geodesic distances between nodes in a network map and is the average geodesic distance that a node is from all other nodes as shown in the network map. CC measures the closeness between the actors/nodes and a measure of how fast information spreads from a given node to other reachable nodes in the network The initial idea of this measure is referred to as a central actor of a network if it can interact with other actors more easily and quickly. Associated with the flow of information, a central actor, who has close relations with other actors, will be more productive as the actor can access the information due to the shorter lines of communication. The mean CC reflects closeness between the actors. If we compare the value of CC in three networks,   network with the best closeness was the network with the lowest   CC's score. Smaller CC indicates the better network; means between actors in the co-authorship relation tend to be closer to each other.

The Betweenness Centrality (BC) of a node reflects the amount of control that this node exerts over the interactions of other nodes in the network. BC shows the average actor in interceding on geodesic distance between actors in the network. Individuals with the highest BC are considered as an actor in control of the flow of information within the network. ITB network was the network with the lowest of CC, means among authors not well connected to each well and actors numbers who have a role to mediate information between actors, geodesic distance between actors would be small and occur geodesic distance is equal to zero, because between the two actors are not connected to each other because they are in different subgroups.

Fig. 3 shows Degree Centrality (DC) distribution of Mathematics and Statistics related studies of Indonesian affiliation scholars. Twenty-five percent of authors in the network had two co-authors, whereas twelve authors had twenty for 79 co-authors. Yan et al. [16] explain that there are "hub" authors that have many co-authors or ties with many authors compared with other authors.

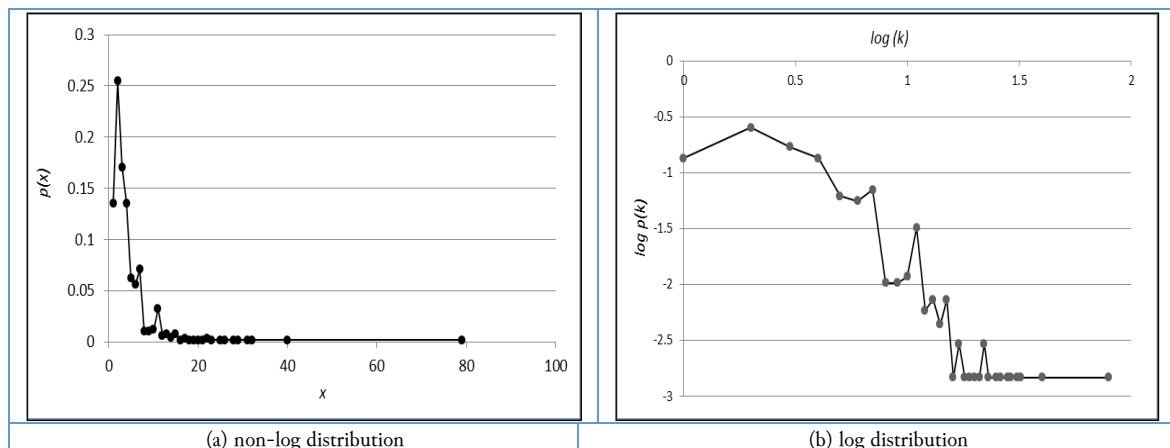| (a) non-log distribution	(b) log distribution

Fig. 3. Degree Centrality (DC) distribution

Those authors are the central actor in the network that connects the other actors. That phenomenon is related to scale-free distribution of author degree. Theoretically, this scale-free distribution of author degree is the power law distribution, Clauset et al. [20], is defined as:

$$p(x) \sim x^{-\alpha} \tag{1}$$

Where x is the degree of node; $p(x)$ is the fraction of nodes in the network that have x degree of centrality and α is constant parameter of the distribution known as the exponent or scaling parameter that usually lies in range of $2 < \alpha < 3$. Clauset et al. [20] address issues on how to test the power law distribution hypothesis, where the hypothesis are 1) data is generated from a power law distribution (H_0), and 2) data is not generated from a power law distribution (H_1).

The hypothesis was tested with goodness of fit statistics, using the bootstrapping procedure, suggest by Gillespie [21]. The hypothesis testing result accepted H_0 with a p value of 0.82. This concluded that the degree of centrality distribution of Mathematics and Statistics related studies of Indonesian affiliation scholars follows the power law distribution. Estimated parameter using MLE (Maximum Likelihood Estimation) shows that the α is 3.13.

Table 7 shows the micro level metric measures, the centrality measure of the top 10 authors. ITB's authors dominated with 8 out of top 10. This result is linear with the number of articles in Table 3. Edy T. Baskoro from ITB, with the highest degree centrality (79). Based on Table 3, Edy T. Baskoro produced 30 articles.

Table 7. Top 10 author centrality measures for co-authorship network of Indonesian affiliation scholars (in all networks) in Mathematics and Statistics related studies

No	Authors	Institution	Degree Centrality	Closeness Centrality	Betweenness Centrality
1	Baskoro, Edy Tri	ITB	79	652	6.063
2	Baca, Martin	Technical University of Košice Slovakia	40	681	4.405
3	Salman, A. N. M.	ITB	32	735	5.152
4	Gunawan, Hendra	ITB	31	746	4.360
5	Semanicova-Fenovcikova, Andrea	Technical University of Košice Slovakia	29	692	6.675
6	Assiyatun, Hilda	ITB	28	748	1.173
7	Pudjaprasetya, S. R.	ITB	26	830	3.155
8	Astuti, Pudji	ITB	25	793	6.808
9	Muchtadi-Alamsyah, Intan	ITB	23	850	6.253
10	Miller, Mirka	ITB	22	767	8.990

There is one big cluster consisting of many authors with a relatively close distance between authors (Fig. 4). This network cluster shows that the members mostly come from ITB. Where ITB's co-authorship network consists of one big cluster and several small clusters. There are 60 ITB scholars in their co-authorship network in the Mathematics and Statistics related studies area.
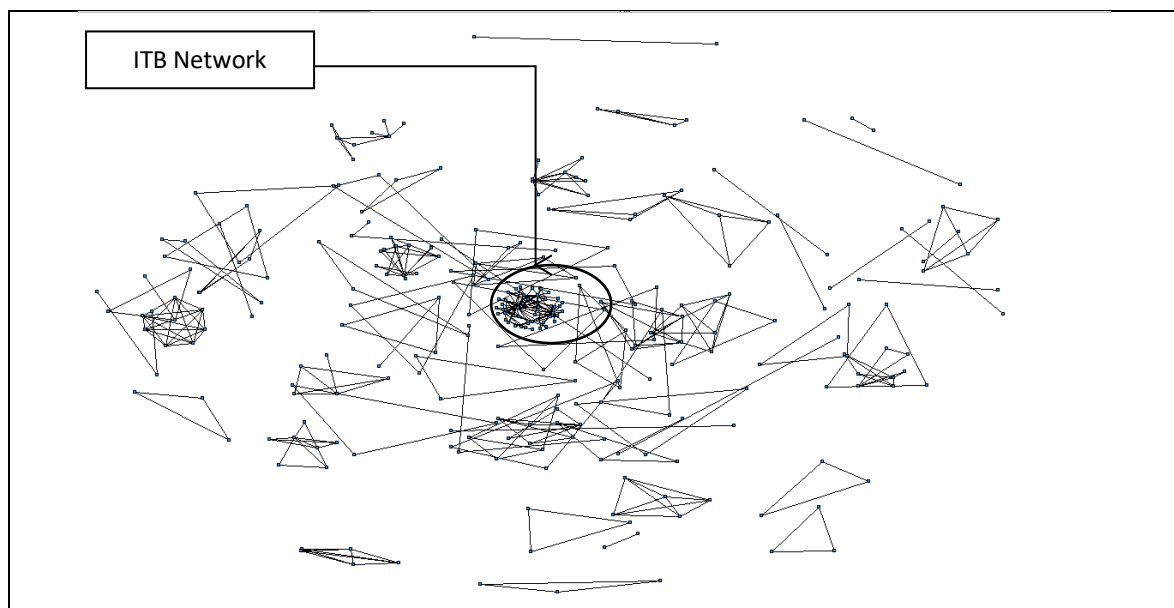

Fig. 4. Co-authorship network of all Indonesian affiliation scholars published on the Mathematics and Statistics studies area

Fig. 5 give the clear picture of co-authorship network for ITB scholars. There are 96 ITB scholars in their co-authorship network in the Mathematics and Statistics related studies area. Those scholars build a co-author relation with 210 scholars from 91 institutions around the world. The ITB's co-authorship network consist of one big cluster and several small clusters.

The big cluster consists of three *central authors,* Baskoro E.T., Salman, A.N.M., and Miller Minka. The clusters consist of 98 authors with 510 ties of co-authorship. Each central author is connected with the other networks within this cluster. There are three authors, Ryan, J., Maryanti, T.K., and Baca, Martin, that have direct connection with all of the central author. Ten authors in the network have direct connection with Baskoro and Salman. While another big cluster in ITB's network was made up of (Pudjaprasetya, S, R) (Gunawan, Hendra) as the central authors. Those cluster is quite big with more than 10 members of authors in each cluster and the others clusters are small with 2 to 5 members.
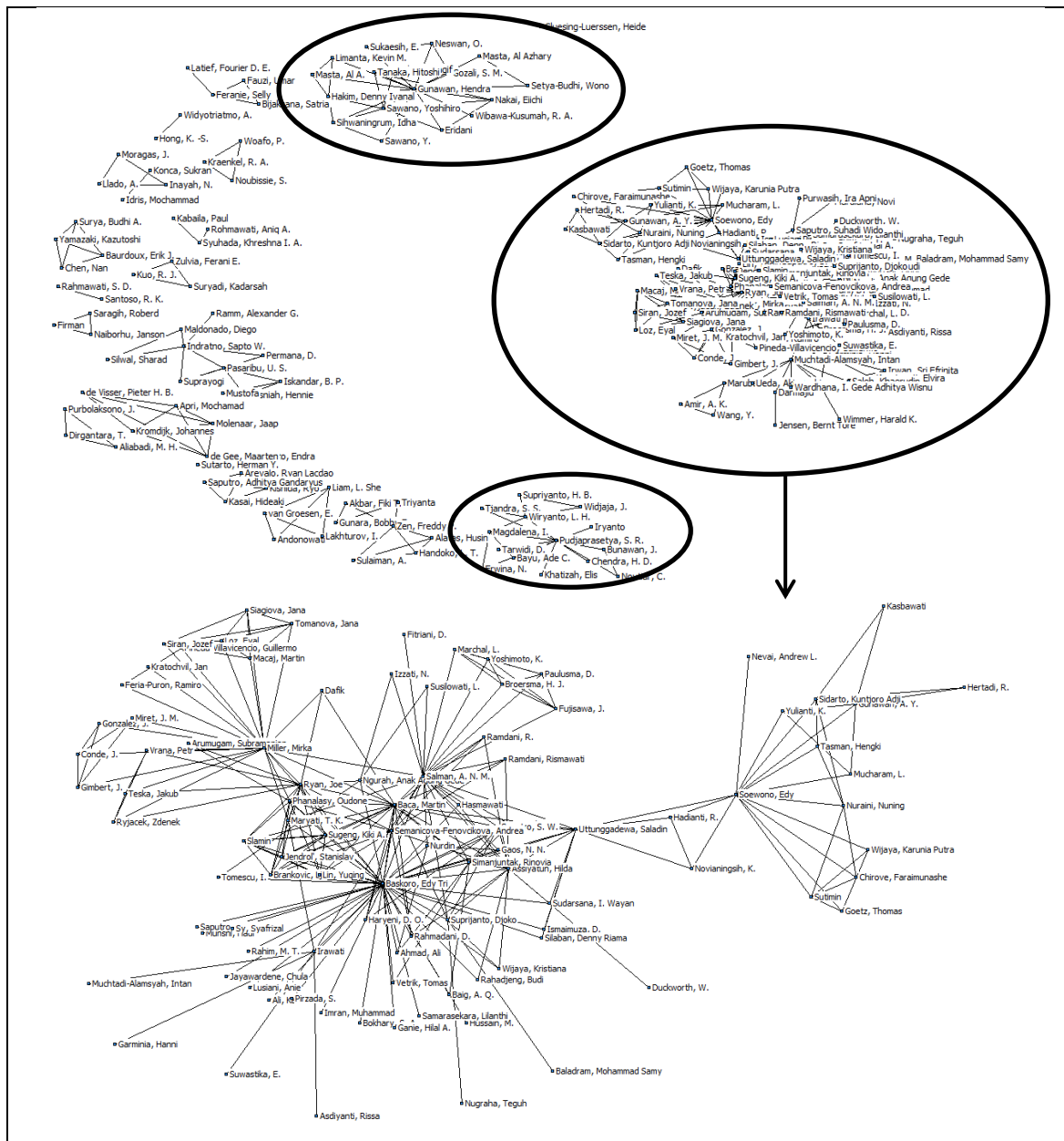
Fig. 5. Co-authorship network of ITB's scholar published on the Mathematics and Statistics studies area

Fig. 6 shows the co-authorship network where ITB is the central affiliation in the Indonesian affiliation network. ITB has direct relation with several big institution such as IPB, Airlangga University, University of Indonesia, etc. Meanwhile, ITB does not have direct relation with UGM (Gadjah Mada University). In general, there are two big network in the institutional level in Indonesia, the one that centered by ITB and the others is centered by UGM.

Fig. 7 shows the keyword density from an analysis of publications of Indonesian affiliation scholars. Keywords were taken from the indexed keyword of the articles. Keyword density was produced by the co-word analysis approach. Co-word analysis is based on the assumption that two keywords co-occurring within different articles are an indication of a link between the articles Wu & Leu [22] and the assumption that they have the same meaning. Co-word analysis is widely used as a methodological approach to explore knowledge discovery in several fields of study. Surjandari et al. [23] mapped research themes of published articles by the top eight universities of Indonesia using co-word analysis.
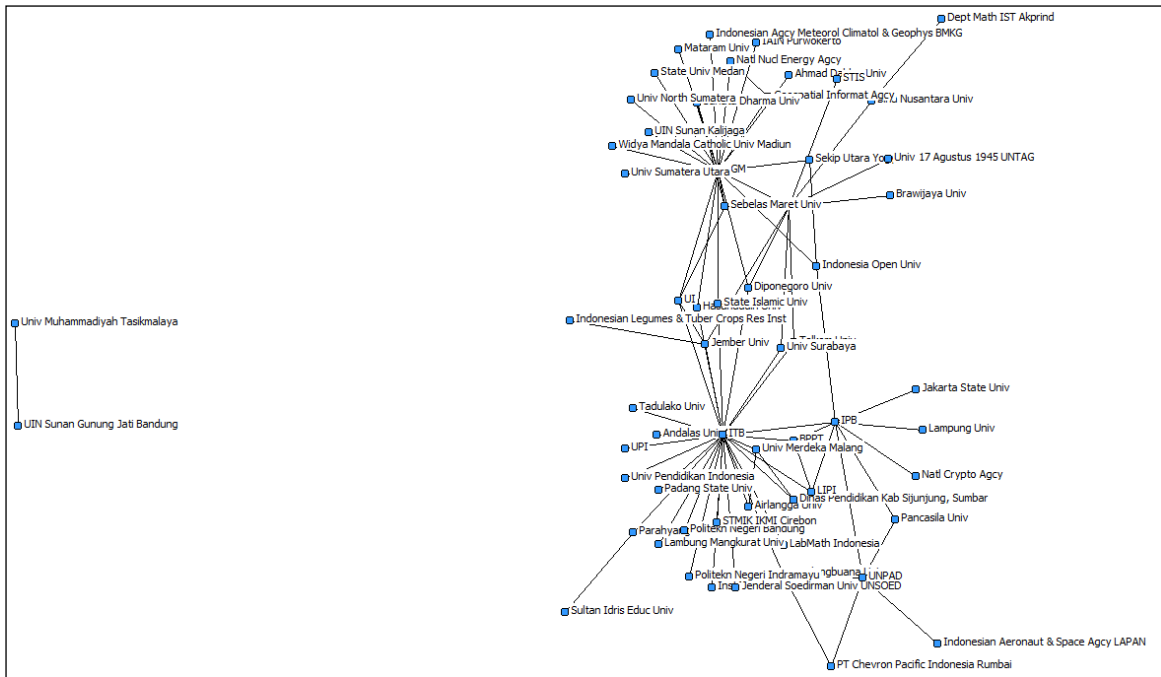
Fig. 6. Co-authorship affiliation network of ITB Indonesian scholars published on the Mathematics and Statistics studies area
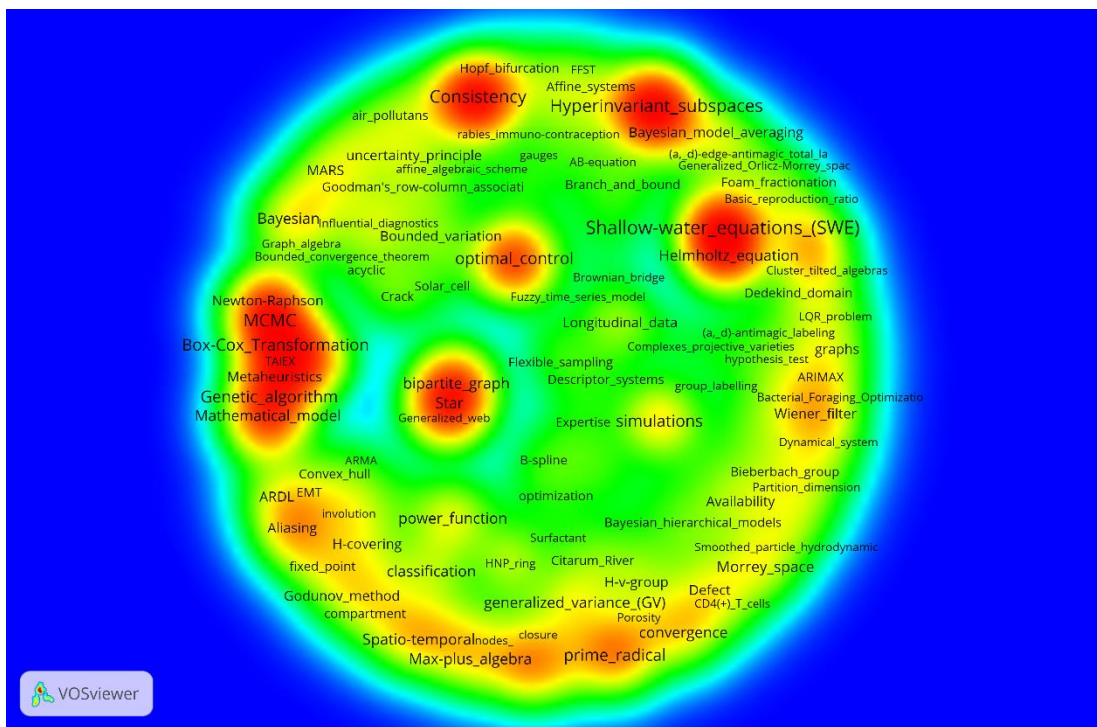

Fig. 7. Keyword density for Indonesian affiliation scholars published on the Mathematics and Statistics studies area

Fig. 7 is the visualization of co-word analysis using VosViewer software. Red color indicates high intensity of occurrence of the keyword. In general, there are 4 big hotspots that consist of many of keyword that are correlated. In first hotspot consist of keyword that related to *consistency test*. The second hotspot is hyper-invariant subspace. Third is Shallow-water equation, and Helmholtz equation. Forth hotspot is related with, such as, Boxcox transformation, Newton-Raphson, Genetic Algorithm, and Mathematical model.

4. Conclusion

Based on nine years data-set of international publications from Indonesian affiliated scholars in Mathematics and Statistics studies area, this research conducted a bibliometrics and scientometrics approach to examine the performance of Indonesian affiliation scholars in that area. This study showed some significant information about the performance of Indonesian affiliation authors and Indonesia academic institutions. Number of articles produced by Indonesian affiliated scholars are still low, only 426 articles during 2009-2017. Forty percent of authors are not affiliated with an Indonesia institution. ITB is the most productive institution with 138 publications from 255 authors. The most productive and efficient author has 30 articles and 79-degree centrality.

Based on macro-level measure of Social Network Analysis, co-authorship network from Indonesia affiliated scholars is a small-world network, where the network was sparse and fragmented. It was also dependent on several central authors to maintain the entire connection within the network. Based on degree distribution, the network is a scale-free network that indicates that some central authors have many connections with other authors while a majority of authors only collaborate with few authors. Co-authorship network in the Indonesian affiliation level shows there are two big cluster, ITB is the biggest network cluster, and UGM's cluster, as the second best-performed institution. Unfortunately, this two big institution are not have direct relation with each other. Co-word analysis found that there are four big cluster of keyword.

Acknowledgment

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