THE COMPARATIVE ANALYSIS OF THE NHH AND BI NETWORKS*

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Abstract

Based on the co-authorship networks of the Norwegian School of Economics (NHH) and the BI Norwegian Business School we present a comparative analysis in terms of structures, collaborations and publications. The networks' structures are based on the NHH and the BI faculties' publications recognized by the ISI Web of Science for the period 1950 – Spring, 2014. The analysed networks cover the publication activities of the NHH and the BI faculty members based on the data retrieved from ISI Web of Science in Spring, 2014.

Keywords: co-authorship networks, social networks analysis.

1. INTRODUCTION

Social networks analysis (SNA) is a powerful tool for analysing the interpersonal relations and different types of cooperation between a variety of social groups such as research or business communities, governmental or private institutions etc. The uniqueness of SNA is its interdisciplinary approach that combines sociology, graph theory, mathematics, psychology etc. (Knoke & Yang 2008). In contrast to pure network analysis, SNA is not concentrated on the structural measurement only, but also takes into consideration the multifactorial social aspects of relations (Carrington, Scott, & Wasserman 2005).

In this study we compare the NHH and the BI social networks based on the coauthorship relations between the faculty members. The resulting coauthorship networks are constructed based on the information retrieved from the *ISI Web of Science* as of March – April, 2014 (ISI Web of Science 2014). The *ISI Web of Science* provides the online scientific citation indexing service of the highly ranked quality journals from cross-disciplinary areas. It is important to note that we use the *ISI Web of Science* as the only source to retrieve the information regarding the NHH and BI faculty members' publications in the period 1950 – Spring, 2014.

The information regarding the analyzed networks is retrieved from Belik, I., & Jörnsten, K. (2014, May) and Belik, I., & Jörnsten, K. (2014, July).

The NHH co-authorship network covers six departments:

1. Department of Business and Management Science;
2. Department of Economics;
3. Department of Strategy and Management;
4. Department of Finance;
5. Department of Accounting, Auditing and Law;
6. Department of Professional and Intercultural Communication.

* The paper uses partly or exclusively text and data from Belik, I., & Jörnsten, K. (2014, May) and Belik, I., & Jörnsten, K. (2014, July)

The resulting BI co-authorship network covers eight departments:
1. Department of Accounting, Auditing and Law;
2. Department of Communication and Culture;
3. Department of Economics;
4. Department of Finance;
5. Department of Innovation and Economic Organisation;
6. Department of Leadership and Organizational Behaviour;
7. Department of Marketing;
8. Department of Strategy and Logistics.

The co-authorship networks' nodes correspond to the faculty members, and the links (i.e., edges) between them correspond to the existence of common publications. Every edge has a weight, which is the number of joint publications. We consider not only the internal departmental and interdepartmental relations between the faculty members, but we also show the external publications with co-authors that are not affiliated with the analyzed schools.

2. THE INTERDEPARTMENTAL CO-AUTHORSHIP NETWORKS

2.1 NHH network

There are 24 out of 156 faculty members at NHH who are involved in interdepartmental collaboration: ten – from the Department of Business and Management Science; seven – from the Department of Economics; two – from the Department of Strategy and Management; one – from the Department of Finance; four – from the Department of Accounting, Auditing and Law (see Table 1).

The overall NHH interdepartmental network that includes 156 faculty members is represented in Figure 1. It is characterized by 85 edges, where 67 edges are internal (i.e., departmental) and 18 – are interdepartmental.

Table 1. NHH faculty members with interdepartmental coauthorship

Department of Business and Management Science		Department of Economics		Department of Accounting, Auditing and Law		Department of Strategy and Management		Department of Finance	
1	node 1	1	node 39	1	node 130	1	node 84	1	node 122
2	node 9	2	node 52	2	node 137	2	node 108		
3	node 10	3	node 53	3	node 138				
4	node 14	4	node 65	4	node 142				
5	node 18	5	node 67						
6	node 21	6	node 68						
7	node 26	7	node 70						
8	node 29								
9	node 30								
10	node 33								

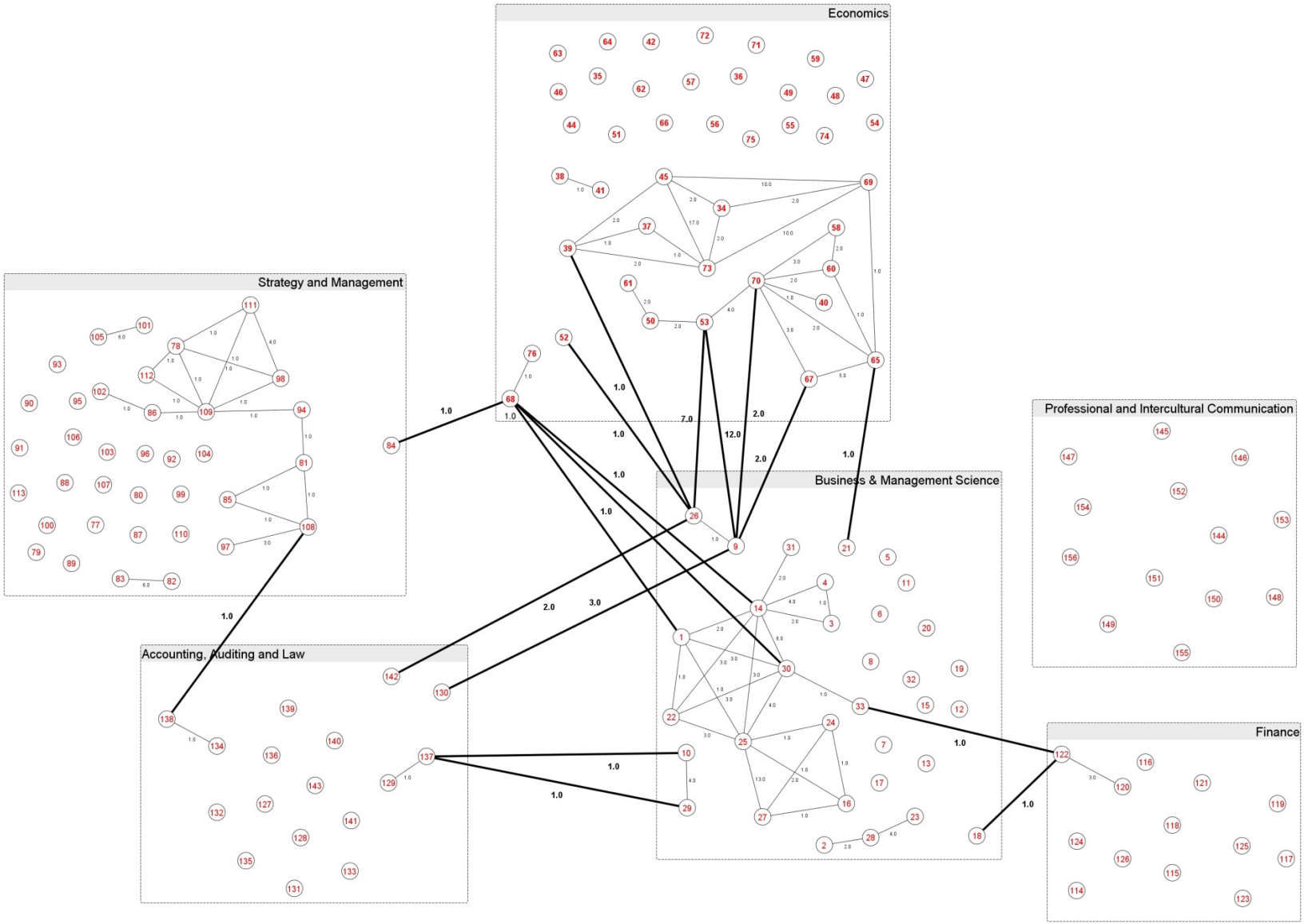

Figure 1. The NHH interdepartmental co-authorship network

2.2 BI network

There are 27 out of 252 BI faculty member who are involved in the interdepartmental collaboration: nine – from the Department of Leadership and Organizational Behaviour; eight – from the Department of Strategy and Logistics; three – from the Department of Communication and Culture; three – from the Department of Innovation and Economic Organisation; one – from the Department of Economics, and one – from the Department of Marketing (see Table 2).

The overall BI interdepartmental network that includes 252 faculty members is represented in Figure 2. It is characterized by 71 edges, where 52 edges are internal (i.e., departmental) and 19 – are interdepartmental.

Table 2. BI faculty members with interdepartmental coauthorship

Department of Leadership and Organizational Behaviour		Department of Strategy and Logistics		Department of Communication and Culture		Department of Accounting, Auditing and Law		Department of Innovation and Economic Organisation		Department of Economics		Department of Marketing	
1	node 154	1	node 224	1	node 56	1	node 11	1	node 138	1	node 78	1	node 212
2	node 162	2	node 233	2	node 66	2	node 39	2	node 148				
3	node 168	3	node 234	3	node 67	3	node 43						
4	node 170	4	node 240										
5	node 171	5	node 241										
6	node 175	6	node 242										
7	node 179	7	node 245										
8	node 180	8	node 250										
9	node 187												

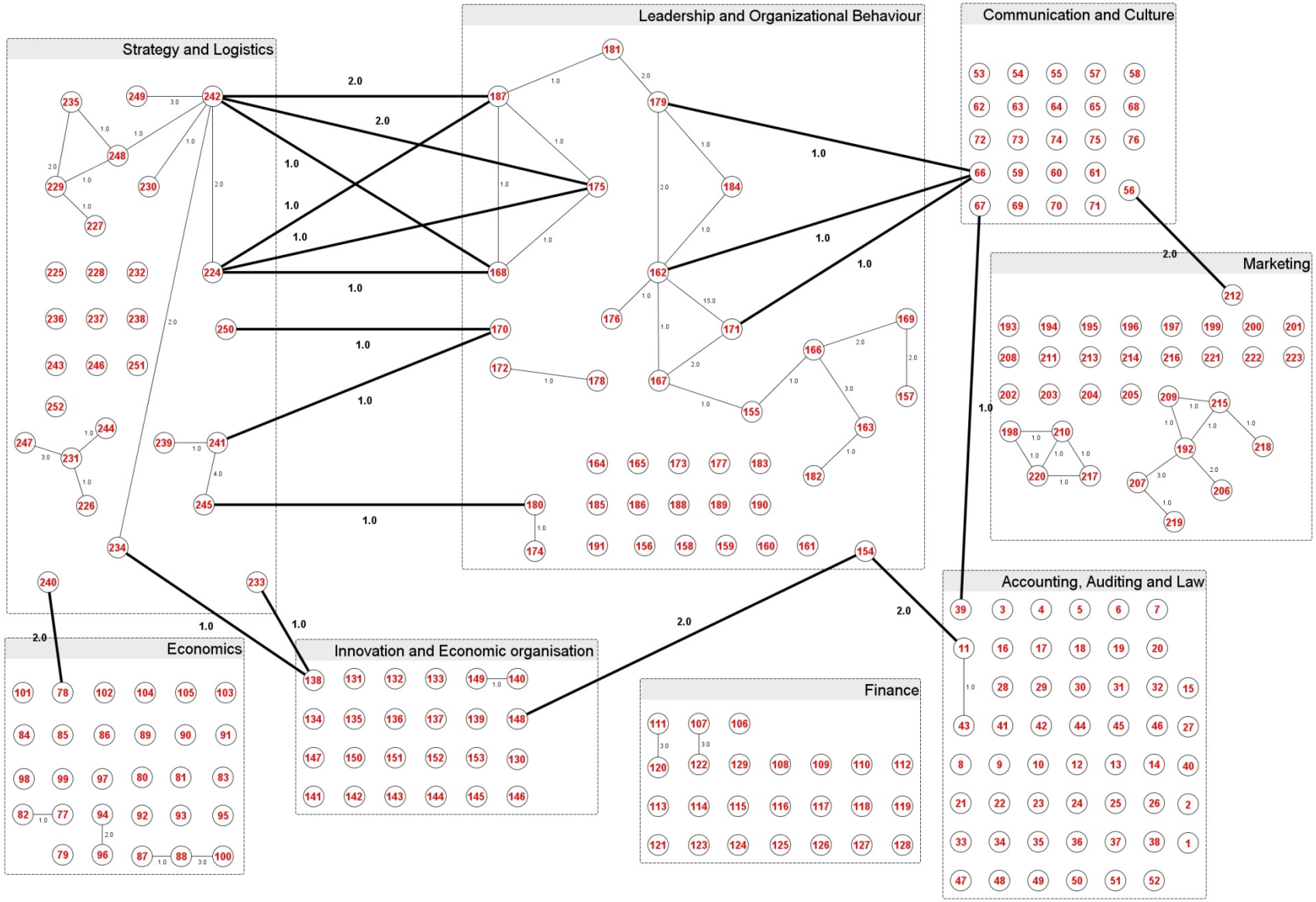

Figure 2. The BI interdepartmental coauthorship network

3. THE ANALYSIS OF CLIQUES

The group of people that is interconnected by the socially strong relations form a clique (Luce & Perry 1949). In terms of graph theory, every pair of persons in the group forming the clique, has to be connected by an edge. Specifically, in terms of the research collaboration, the faculty members form cliques if each of them has published a joint scientific paper(s) with all other clique members.

In terms of this paper, we are looking for the *k*-cliques (with $k \geq 3$) in the coauthorship networks within the departmental and interdepartmental collaborations, where *k* is the number of faculty members forming the clique. The trans-departmental cliques are considered as the cliques where $k \geq 3$ and at least two clique members are the members of different departments.

3.1 NHH cliques

3.1.1 NHH departmental cliques

The maximum clique is detected in the Department of Business & Management Science. It consists of five faculty members:
1. node 1;
2. node 14;
3. node 22;
4. node 25;
5. node 30.

The second largest clique (*k*=4) within the given department contains four faculty members:
1. node 16;
2. node 24;
3. node 25;
4. node 27.

The core clique-based structure of the Department of Business & Management Science consists of three cliques interconnected by two hubs: node 25 and node 14. This is illustrated in Figure 3.

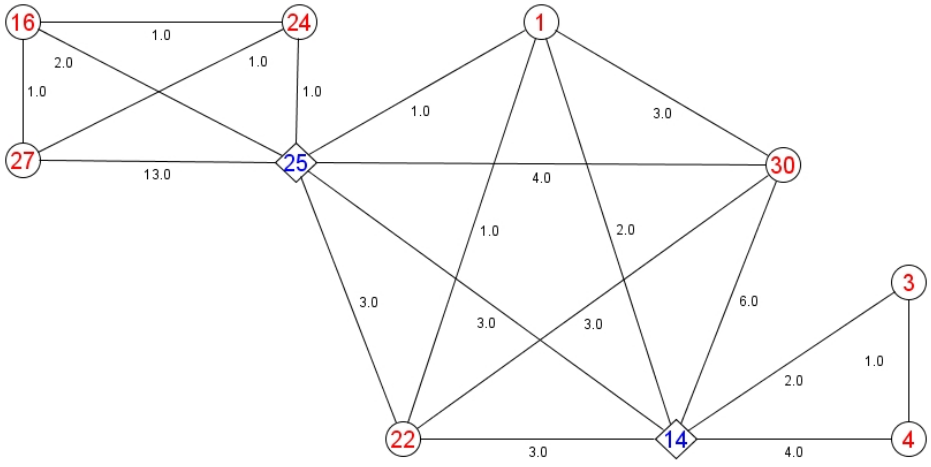

Figure 3. Core clique-based structure of the Department of Business and Management Science

The second four-node clique is detected in the Department of Economics and it consists of four faculty members:
1. node 34;
2. node 45;
3. node 69;
4. node 73.

Next, there are five cliques of size *k*=3 within the Department of Economics that are not the sub-graphs of the given four-vertex clique. All departmental cliques are represented in Figure 4.

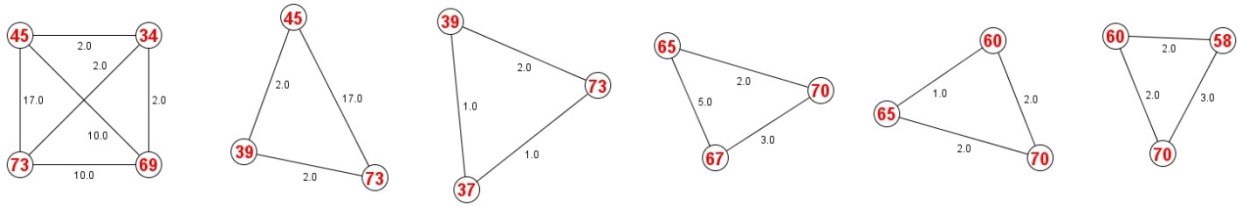

Figure 4. Cliques within the Department of Economics

The cliques' interconnection is represented in Figure 5. According to the given representation it is clear that there are two large subcomponents (i.e., Component 1 and Component 2) connected by the only edge "node 65 – node 69". Obviously, the role of this edge is critical due to its "bottleneck" nature. The breakdown of this edge would lead to the disconnection of the two largest clique-based sub-graphs (i.e., Component 1 and Component 2).

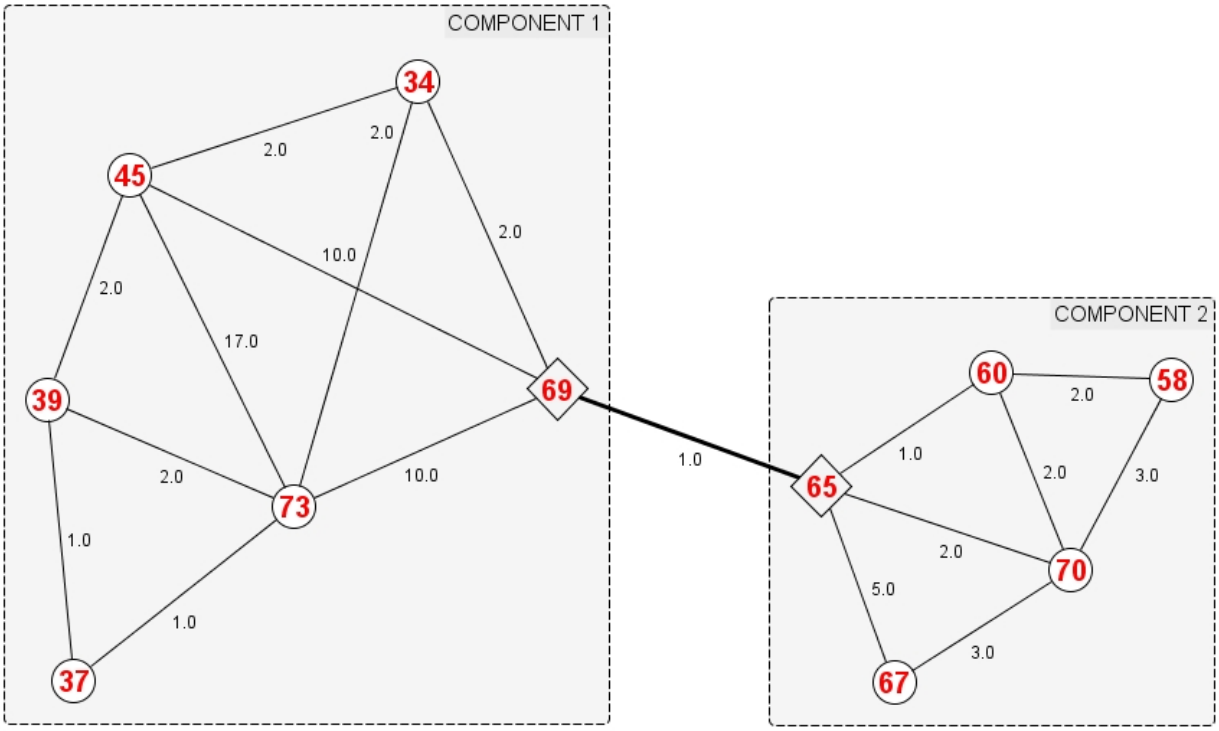

Figure 5. Core clique-based structure of the Department of Economics

The third four-node clique is detected in the Department of Strategy and Management. It consists of the following faculty members:
1. node 78;
2. node 98;
3. node 109;
4. node 111.

In addition, there are two three-vertex cliques within the Department of Strategy and Management:

Clique 1:	*Clique 2:*
1. node 78;	1. node 81;
2. node 109;	2. node 85;
3. node 112.	3. node 108.

The core clique-based structure of the Department of Strategy and Management consists of three cliques. The first three-vertex *Clique 1* is interconnected with the four-node clique by the participation of two faculty members (i.e., node 109 and node 78) in both cliques. It forms Component 1. The second three-vertex clique (i.e., *Clique 2*) forms Component 2. Both components are connected by the only hub-node "node 94" that has publications with the members of both clique-based components. The overall clique-based structure for the department is represented in Figure 6.

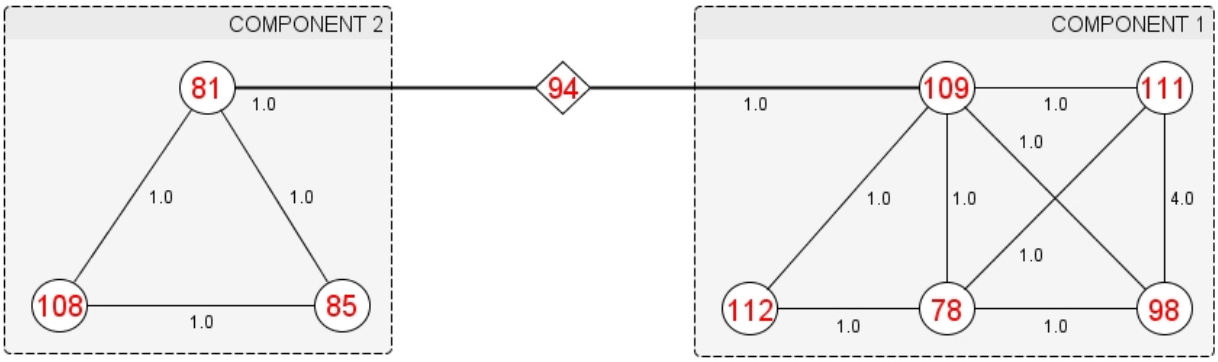

Figure 6. Core cliques-based structure of the Department of Strategy and Management

3.1.2 NHH trans-departmental cliques

The maximum trans-departmental cliques are detected within three departments:

1. Department of Economics;
2. Department of Business and Management Science;
3. Department of Accounting, Auditing and Law.

The maximum trans-departmental clique have the size of k=4.
There are seven three-vertex cliques that are split into three graphs (see Figure 7).

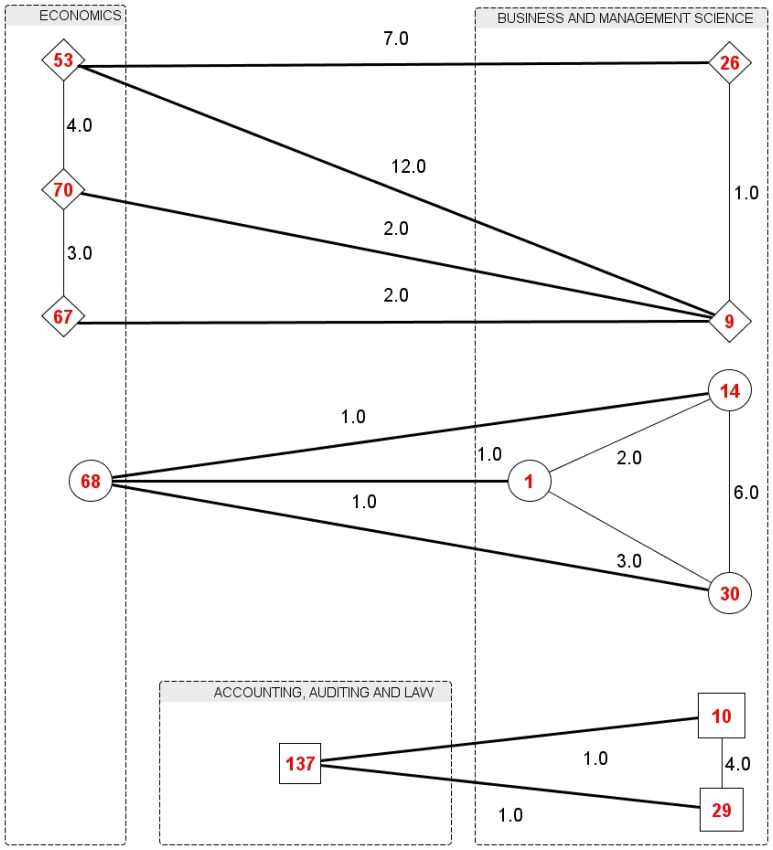

Figure 7. NHH trans-departmental cliques

The first graph consists of five faculty members forming three cliques within the Department of Economics and the Department of Business and Management Science:

1. “node 53” – “node 26” – “node 9”;
2. “node 53” – “node 9” – “node 70”;
3. “node 70” – “node 9” – “node 67”.

The second graph consists of four faculty members (within the Department of Economics and the Department of Business and Management Science) forming three interdepartmental cliques:

1. “node 68” – “node 14” – “node 1”;
2. “node 68” – “node 1” – “node 30”;
3. “node 68” – “node 14” – “node 30”.

The third graph includes three faculty members forming one three-vertex clique within the Department of Business and Management Science and the Department of Accounting, Auditing and Law: “node 10” – “node 29” – “node 137”.

3.2 BI cliques

3.2.1 BI departmental cliques

The largest clique in the BI network has size k=4 and can be found in the marketing department. There are seven cliques of size *k*=3, which are represented within three departments out of eight:

1. Department of Leadership and Organizational Behaviour;
2. Department of Marketing;
3. Department of Strategy and Logistics.

All seven three-vertex cliques are represented in Figure 8:

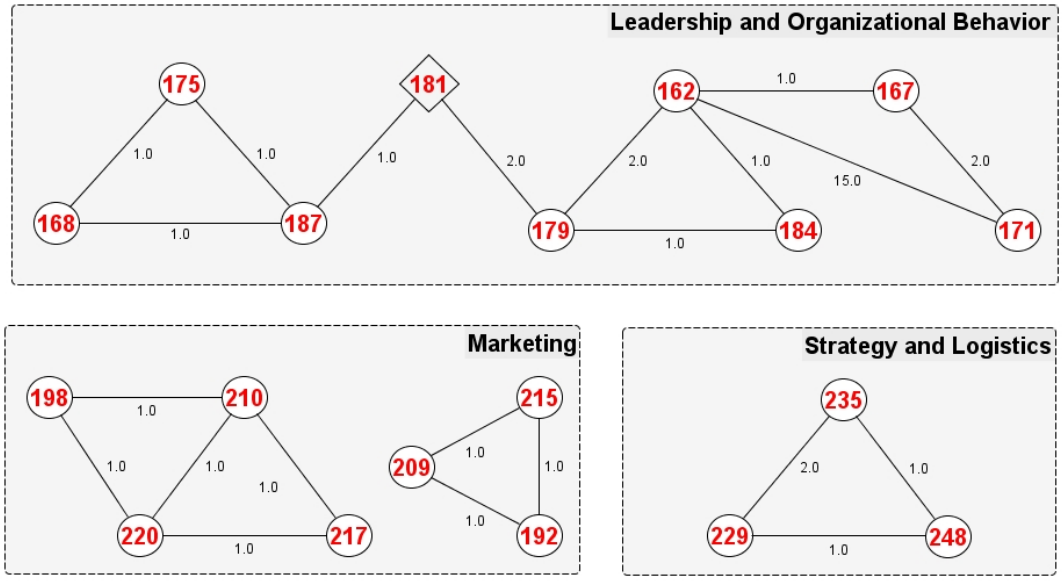

Figure 8. Three-vertex cliques within three departments

Cliques in the Department of Leadership and Organizational Behaviour:
(a) node 168 – node 175 – node 187;
(b) node 162 – node 179 – node 184;
(c) node 162 – node 167 – node 171.

Cliques in the Department of Marketing:
(d) node 198 – node 210 – node 220;
(e) node 210 – node 217 – node 220;
(f) node 192 – node 209 – node 215.

Cliques in the Department of Strategy and Logistics:
(g) node 229 – node 235 – node 248;

According to Figure 8 the core clique-based structure of the Department of Leadership and Organizational Behaviour is interconnected by the only hub-node “node 181” that is out of any clique, but it has publications with the members from both **(a)** and **(b)** cliques. Cliques **(b)** and **(c)**

are connected to each other by the joint component “node 162”. In the Department of Marketing cliques **(d)** and **(e)** are interconnected by the joint components “node 220” and “node 210”.

3.2.2 BI inter-departmental cliques

There are three trans-departmental cliques detected in the BI coauthorship network (see Figure 9).

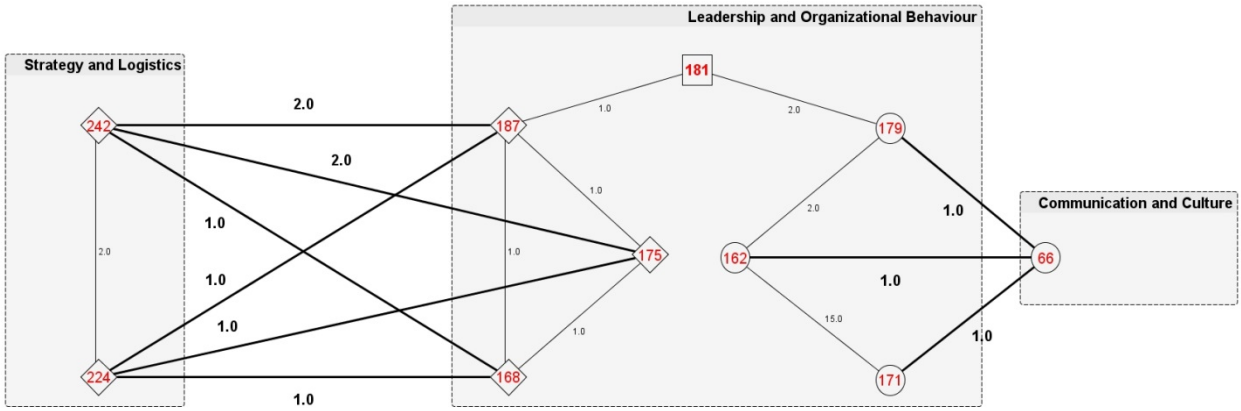

Figure 9. BI trans-departmental cliques

The maximum trans-departmental clique consists of five faculty members: “node 168”, “node 175”, “node 187”, “node 224”, and “node 242”. It is detected within two departments:

1. Department of Leadership and Organizational Behaviour;
2. Department Strategy and Logistics.

The second and third trans-departmental cliques are detected within the following departments:

1. Department of Leadership and Organizational Behaviour;
2. Department of Communication and Culture.

Specifically, there are two three-vertex cliques that contain the following faculty members:

1. “node 66” – “node 162” – “node 179”;
2. “node 66” – “node 162” – “node 171”;

It is important to notice the maximum clique is interconnected with the three-vertex cliques by the only hub “node 181” (see Figure 9). Obviously, the role of this hub is critical due to its “bottleneck”-nature. The deletion of this node would lead to the disconnection of the two largest clique-based trans-departmental sub-graphs.

Comparing two schools based on clique formation it is interesting to note that the maximum clique in the NHH is formed within one department whereas the maximum clique in the BI network contains faculty members from two departments. It shall also be noticed that in both

schools there are departments with little or no cooperation with other departments in terms of co-authorship.

4. SPANNING TREES AND SPANNING FORESTS

We analyze the departmental and interdepartmental co-authorship networks in order to detect the trans-departmental spanning trees and forests. Spanning tree is the minimal set of the network's edges (i.e., links) that connect the maximal number of nodes (i.e., faculty members) with no cycles (Cormen, Leiserson, Rivest, & Stein 2003). Due to the fact that NHH and BI coauthorship networks are represented by the set of disconnected graphs, we are looking for the sets of spanning trees of the disconnected components, which are called spanning forests (Bollobás 1998). Trans-departmental spanning forest is the set of interdepartmental spanning trees, where at least one edge in each of these trees connects the faculty members from different departments.
Analyzing cliques in Section 3 we detected the groups of the most strongly connected faculty members in terms of the coauthorship, but in detecting the spanning trees and forests we are looking for the overall affiliation of the faculty members with the research communities. Spanning forest structure ignores the detailed interpersonal relations due to the requirement to avoid cycles, but it shows the spreading of the different research interests over the NHH and BI coauthorship networks. We analyze the spanning forests for each department separately and then we build the spanning forest for the interdepartmental relations.

4.1 NHH trans-departmental spanning forest

The overall trans-departmental spanning forest is formed based on the coauthorship network of five departments:
1. Department of Business and Management Science;
2. Department of Economics;
3. Department of Strategy and Management;
4. Department of Finance;
5. Department Accounting, Auditing and Law.

The NHH trans-departmental spanning forest includes 57 out 156 faculty members.
The structure is represented in Figure 10.

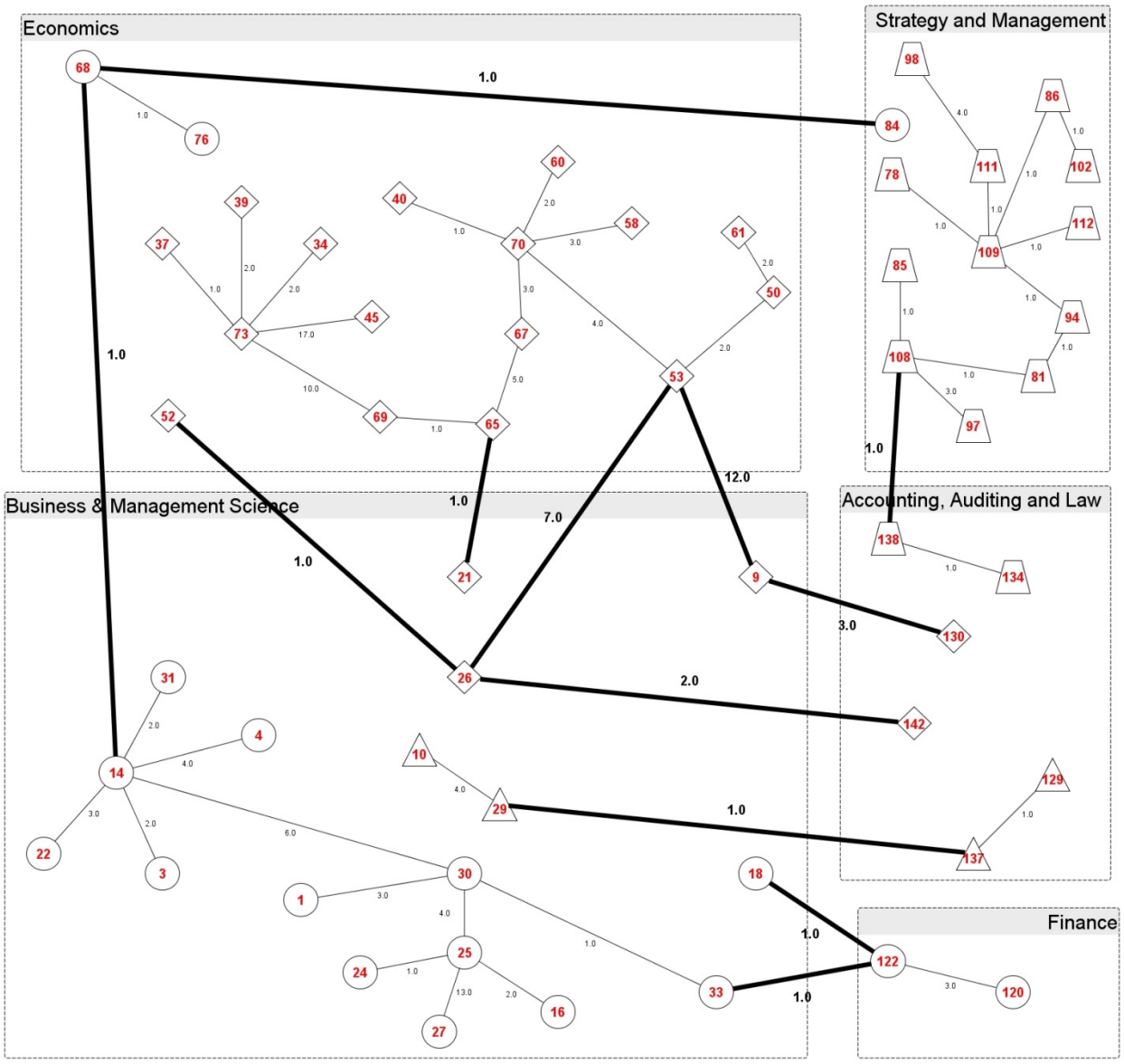

Figure 10. NHH trans-departmental spanning forest

According to Figure 10, the spanning forest consists of four spanning trees.
The maximal spanning tree (see Figure 11) covers three departments and includes 21 faculty members listed in Table 3.

Table 3. Maximal spanning tree in the NHH trans-departmental forest

Department of Economics				Department of Business and Management Science		Department of Accounting, Auditing and Law	
1	node 34	9	node 58	17	node 9	20	node 130
2	node 37	10	node 60	18	node 21	21	node 142
3	node 39	11	node 61	19	node 26		
4	node 40	12	node 65				
5	node 45	13	node 67				
6	node 50	14	node 69				
7	node 52	15	node 70				
8	node 53	16	node 73				

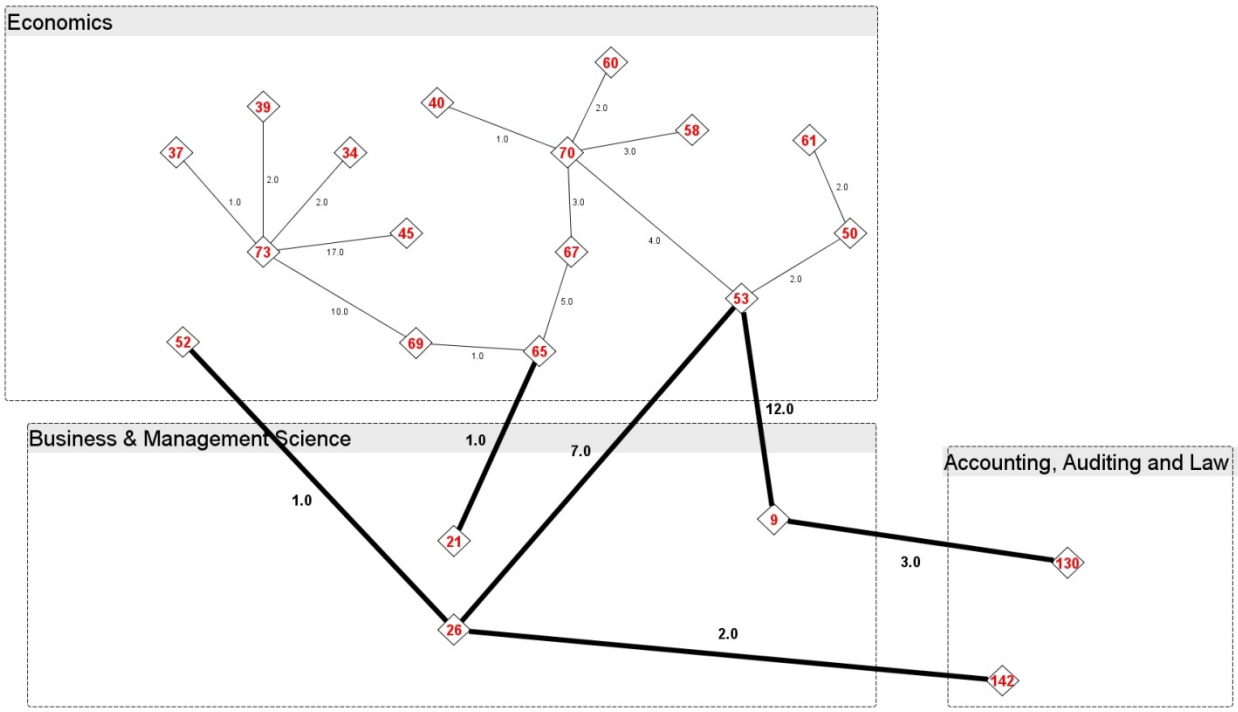

Figure 11. Maximal spanning tree in the NHH trans-departmental forest

The second largest spanning tree consists of 18 faculty members from four departments (see Table 4):

1. Department of Business and Management Science;
2. Department of Economics;
3. Department of Finance;
4. Department of Strategy and Management.

Table 4. The second largest spanning tree in the NHH trans-departmental forest

Department of Business and Management Science				Department of Economics		Department of Finance		Department of Strategy and Management	
1	node 1	8	node 24	14	node 68	16	node 120	18	node 84
2	node 3	9	node 25	15	node 76	17	node 122		
3	node 4	10	node 27						
4	node 14	11	node 30						
5	node 16	12	node 31						
6	node 18	13	node 33						
7	node 22								

The spanning tree that corresponds to Table 4 is represented in Figure 12.

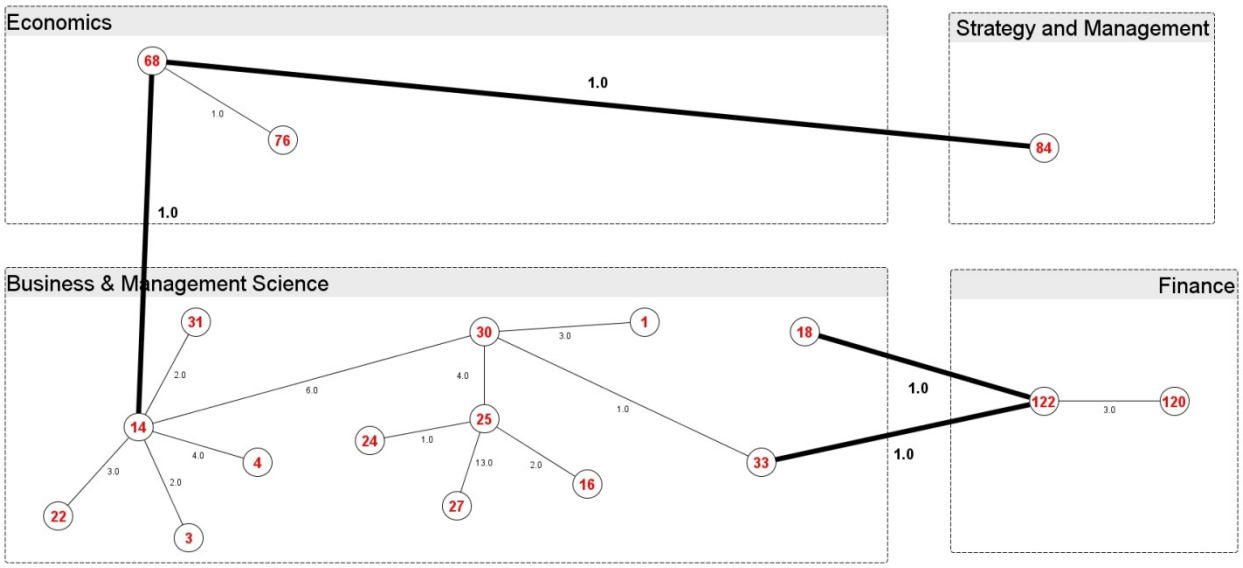

Figure 12. The Second largest spanning tree in the NHH trans-departmental forest

The third largest spanning tree is based on the coauthorship relations between the Department of Strategy and Management and the Department of Accounting, Auditing and Law (see Figure 13). The given spanning tree is formed based on 14 faculty members represented in Table 5.

Table 5. The third largest spanning tree in the trans-departmental forest

Department of Strategy and Management				Department of Accounting, Auditing and Law	
1	node 78	7	node 98	13	node 134
2	node 81	8	node 102	14	node 138
3	node 85	9	node 108		
4	node 86	10	node 109		
5	node 94	11	node 111		
6	node 97	12	node 112		

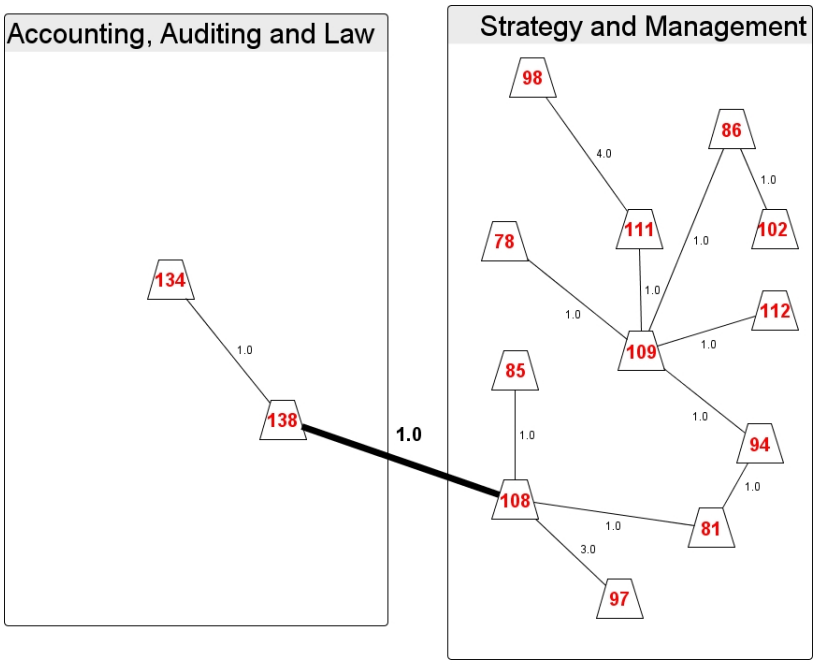

Figure 13. The third largest spanning tree in the NHH trans-departmental forest

The fourth (the smallest) spanning tree consists of four faculty members: node 10 and node 29 – from the Department of Business and Management Science; node 129 and node 137 – from the Department of Accounting, Auditing and Law. The structure of the given spanning tree is represented in Figure 14.

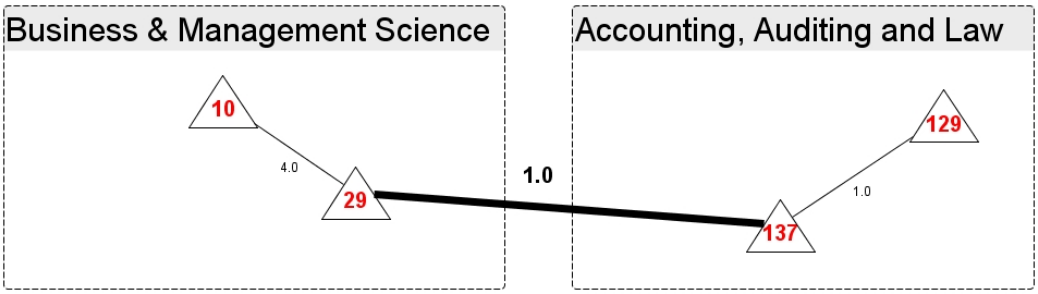

Figure 14. The smallest spanning tree in the NHH trans-departmental forest

4.2 BI trans-departmental spanning forest

The overall trans-departmental spanning forest is formed based on the co-authorship network of seven departments:

1. Department of Accounting, Auditing and Law;
2. Department of Communication and Culture;
3. Department of Economics;
4. Department of Innovation and Economic Organisation;
5. Department of Leadership and Organizational Behaviour;
6. Department of Marketing;
7. Department of Strategy and Logistics.

The BI trans-departmental spanning forest includes 45 out 252 faculty members.
The spanning forest structure is represented in Figure 15.

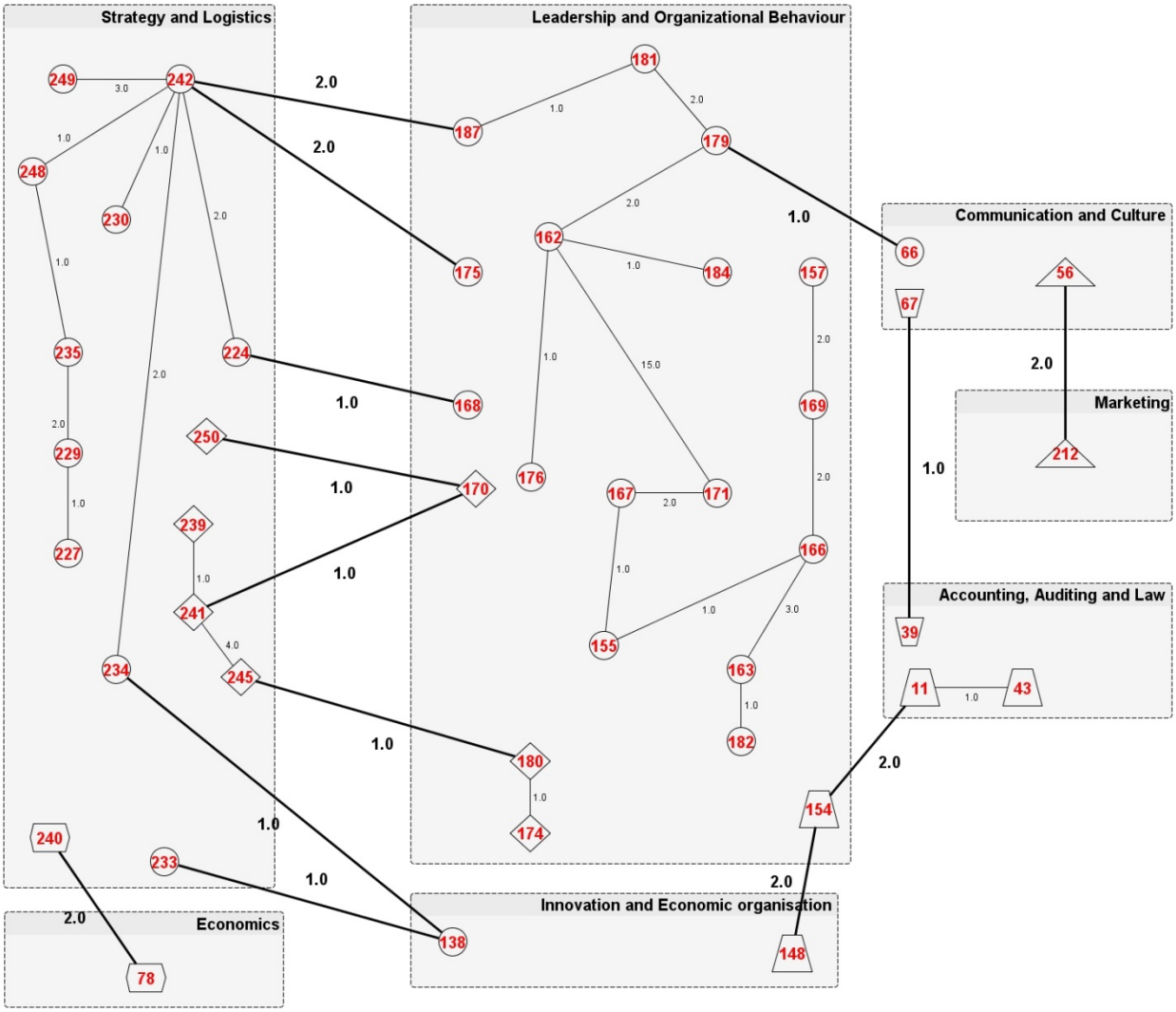

Figure 15. BI trans-departmental spanning forest

According to Figure 15, the spanning forest consists of six spanning trees.
The maximal spanning tree (see Figure 16) covers four departments and includes 28 faculty members listed in Table 6.

Table 6. Maximal spanning tree in the BI trans-departmental forest

Department of Leadership and Organizational Behaviour				Department of Strategy and Logistics		Department of Communication and Culture		Department of Innovation and Economic Organization	
1	node 155	9	node 171	17	node 224	27	node 66	28	node 138
2	node 157	10	node 175	18	node 227				
3	node 162	11	node 176	19	node 229				
4	node 163	12	node 179	20	node 230				
5	node 166	13	node 181	21	node 233				
6	node 167	14	node 182	22	node 234				
7	node 168	15	node 184	23	node 235				
8	node 169	16	node 187	24	node 242				
				25	node 248				
				26	node 249				

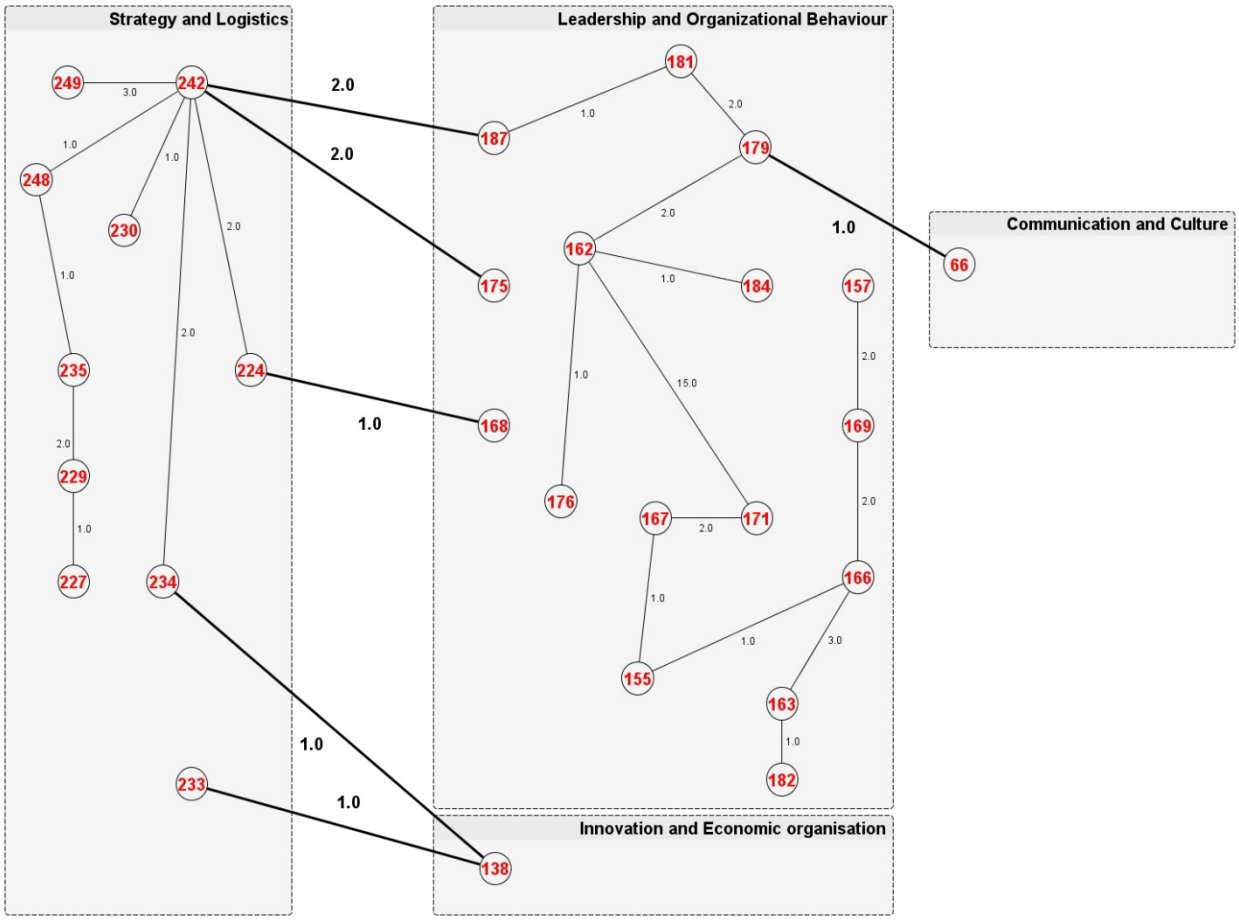

Figure 16. Maximal spanning tree in the BI trans-departmental forest

The second largest spanning tree consists of seven faculty member from two departments (see Table 7):

Table 7. The second largest spanning tree in the BI trans-departmental forest

Department of Strategy and Logistics		Department of Leadership and Organizational Behaviour	
1	node 239	1	node 170
2	node 241	2	node 174
3	node 245	3	node 180
4	node 250		

The spanning tree that corresponds to Table 7 is represented in Figure 17.

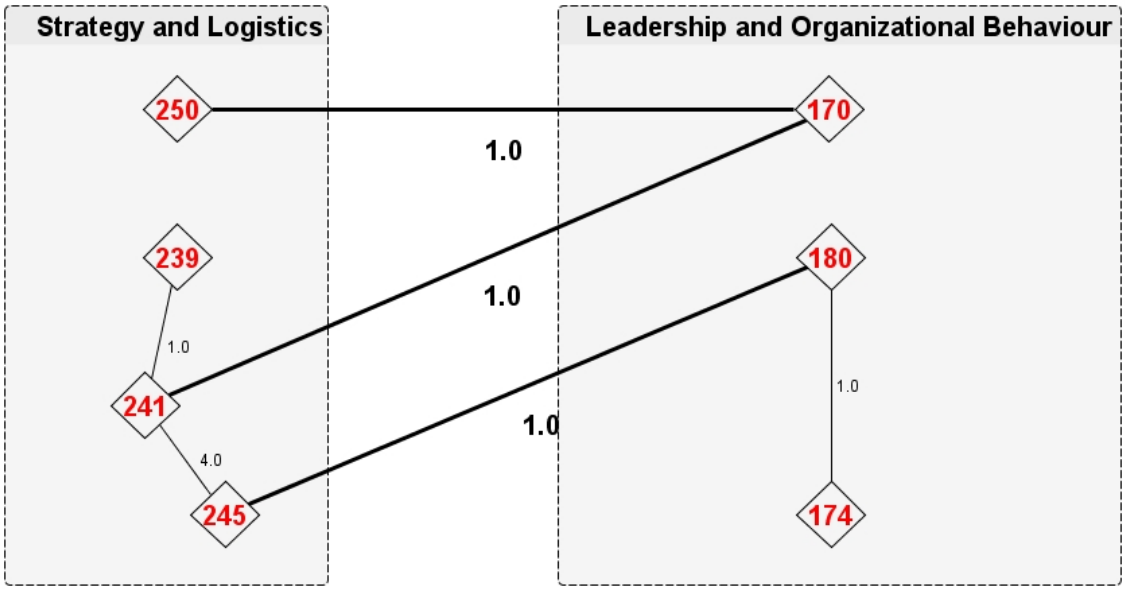

Figure 17. Second largest spanning tree in the BI trans-departmental forest

The third largest spanning tree (see Figure 18) is based on the coauthorship relations between the Department of Accounting, Auditing and Law ("node 11" and "node 43"), the Department of Innovation and Economic Organisation ("node 148"), and the Department of Leadership and Organizational Behaviour ("node 154").

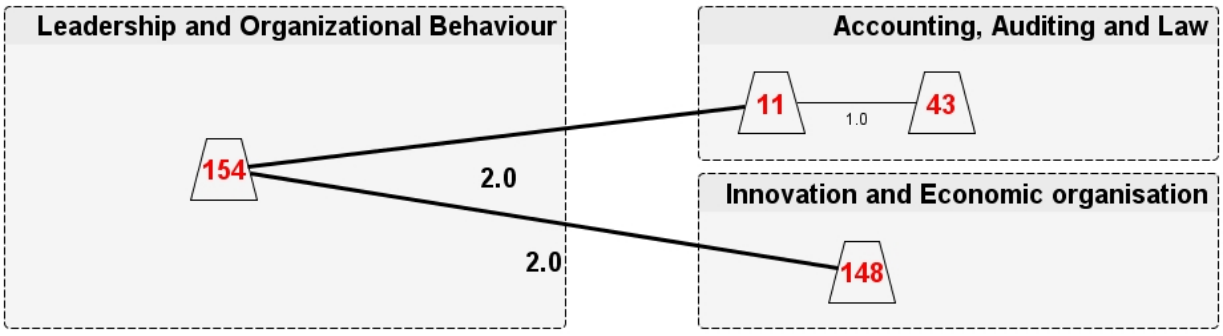

Figure 18. The third largest spanning tree in the BI trans-departmental forest

The fourth, fifth and sixth spanning trees are two-vertex trans-departmental connections represented in Figure 19.

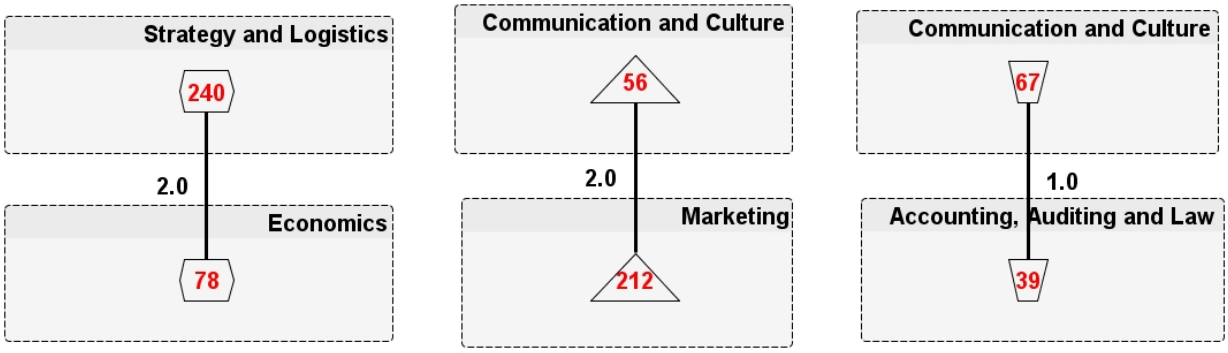

Figure 19. Fourth, fifth and sixth spanning trees in the BI trans-departmental forest

Notable is that the largest spanning tree in the BI spanning forest contains more faculty members (28 members) than the maximal spanning tree at the NHH spanning forest (21 members). Nevertheless, the NHH spanning forest is larger (specifically, 57 out of 156 members) than BIs, which contains only 45 out of 252 members.

5. INTERNATIONAL CO-AUTHORSHIP

In this section, we analyse the existing international co-authorship (based on the *ISI Web of Science*) that covers all countries except Norway. We investigate how many faculty members in the NHH and BI co-authorship networks should be deleted in order for the international co-authorship to vanish. To approach this goal, we sort the faculty members by the number of international co-authorship (i.e., by the number of co-authors from non-Norwegian institutions) in descending order. Then, we delete them from the list one by one until the international coauthorship vanishes.

We represent the results in tabular format in Appendix A and Appendix B where we provide the following information:

- "number of co-authorship" is the number of international co-authors for the corresponding faculty member;
- "overall after exclusion" is the number of the overall international co-authorship left after excluding the current author and authors excluded earlier in the sorted list.
- "% out of overall co-authorship" is the percentage of the faculty member's contribution out of the overall NHH international co-authorship.
- "Overall % after exclusion" is the overall percentage of international co-authorship after excluding the current author and authors excluded earlier in the sorted list.

The graphical representation is given in Figures 20-21.

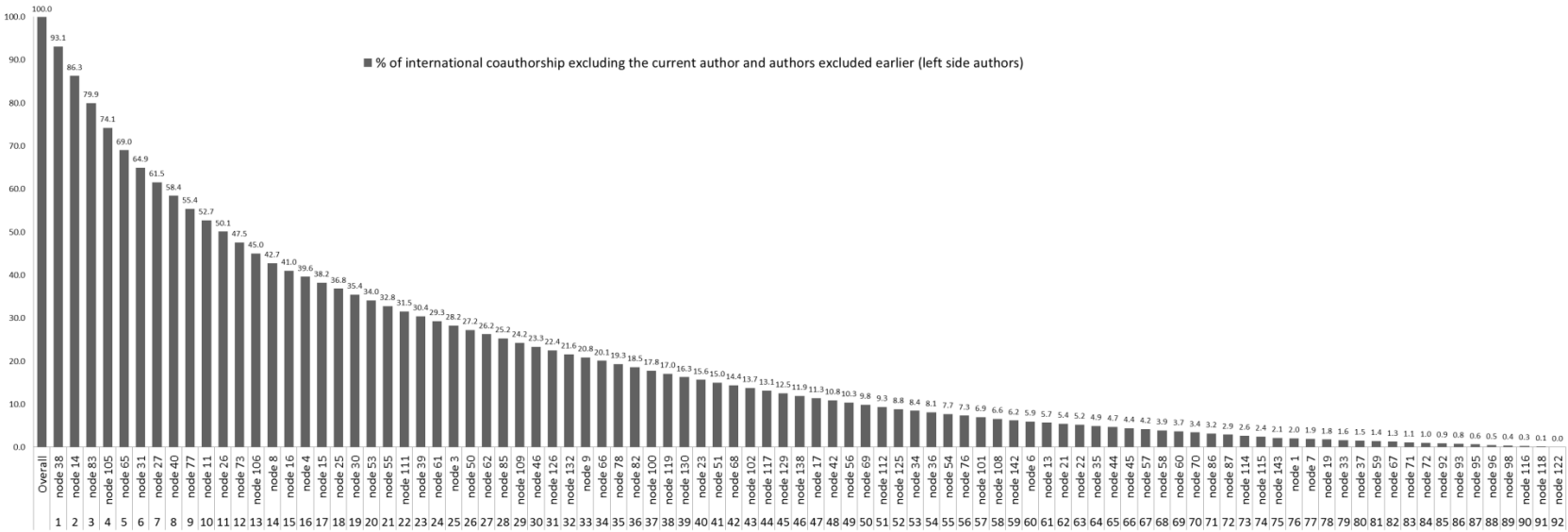

Figure 20. Overall NHH international coauthorship based on the sequential faculty members' deletion

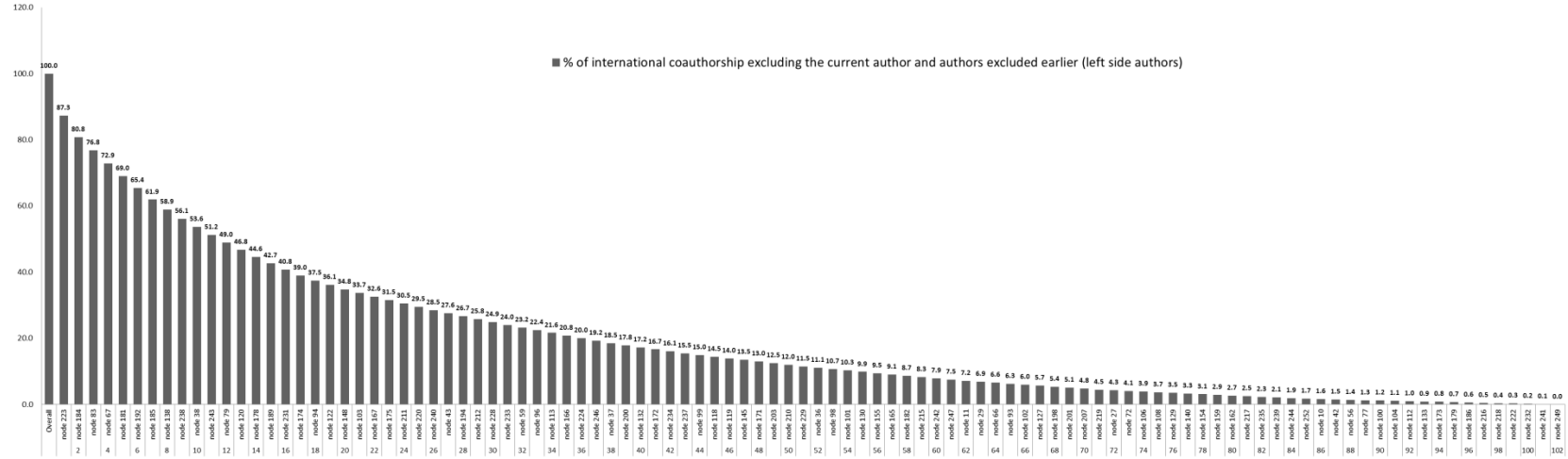

Figure 21. Overall BI international coauthorship based on the sequential faculty members' deletion

The number of the overall international co-authors at NHH is equal to 793 over 156 faculty members. The sorted list of faculty members is represented in Appendix A. The deletion of 92 out of 156 (approximately, 59% out of 100%) faculty members will lead to the vanishing of the international co-authorship. It is important to notice that the deletion of 11 out of 156 faculty members (i.e., approx. 7% out of 100%) will lead to almost 50% reduction of the departmental international co-authorship. The given results (in percentage terms) are represented in Figure 20. On average, NHH is characterized by 5.08 international coauthors per faculty member.

Regarding the BI international co-authors, there are 1003 international coauthors that were detected over 252 faculty members. The sorted list of faculty members is represented in Table 21. The deletion of 102 out 252 of (approximately, 40% out of 100%) faculty members will lead to the vanishing of the international co-authorship. It is important to notice that the deletion of 11 out of 252 faculty members (i.e., approx. 4% out of 100%) will lead to almost 50% reduction of the BI international coauthorship.The given results (in percentage terms) are represented in Figure 21. On average, BI is characterized by 3.98 international coauthors per faculty member.

For both schools relatively few faculty members are creating the core of the school international cooperation in form of coauthorship.

6. THE PUBLICATIONS-BASED ANALYSIS

In this section, we analyze the research activity of the NHH and the BI faculty members in terms of the publications indexed by the *ISI Web of Science.* Initially, we extracted the faculty members that have at least 20 publications and sorted them in descending order. Next, we started to delete the faculty members from the sorted lists one by one in order to track the overall research contribution of the most published faculty members. The results for NHH are represented in Table 8 and in Figure 22, and for BI – in Table 9 and in Figure 23.

Table 8. Publications by faculty members at NHH

	Faculty	number of publications	Overall after exclusion	% out of overall publications	Overall % after exclusion
1	node 14	64	1214	5.0	95.0
2	node 31	58	1156	4.5	90.5
3	node 83	56	1100	4.4	86.1
4	node 65	38	1062	3.0	83.1
5	node 73	37	1025	2.9	80.2
6	node 30	33	992	2.6	77.6
7	node 70	33	959	2.6	75.0
8	node 100	31	928	2.4	72.6
9	node 26	29	899	2.3	70.3
10	node 38	29	870	2.3	68.1
11	node 33	26	844	2.0	66.0
12	node 25	24	820	1.9	64.2
13	node 53	24	796	1.9	62.3
14	node 85	23	773	1.8	60.5
15	node 9	21	752	1.6	58.8
16	node 15	21	731	1.6	57.2
17	node 45	21	710	1.6	55.6
18	node 27	20	690	1.6	54.0

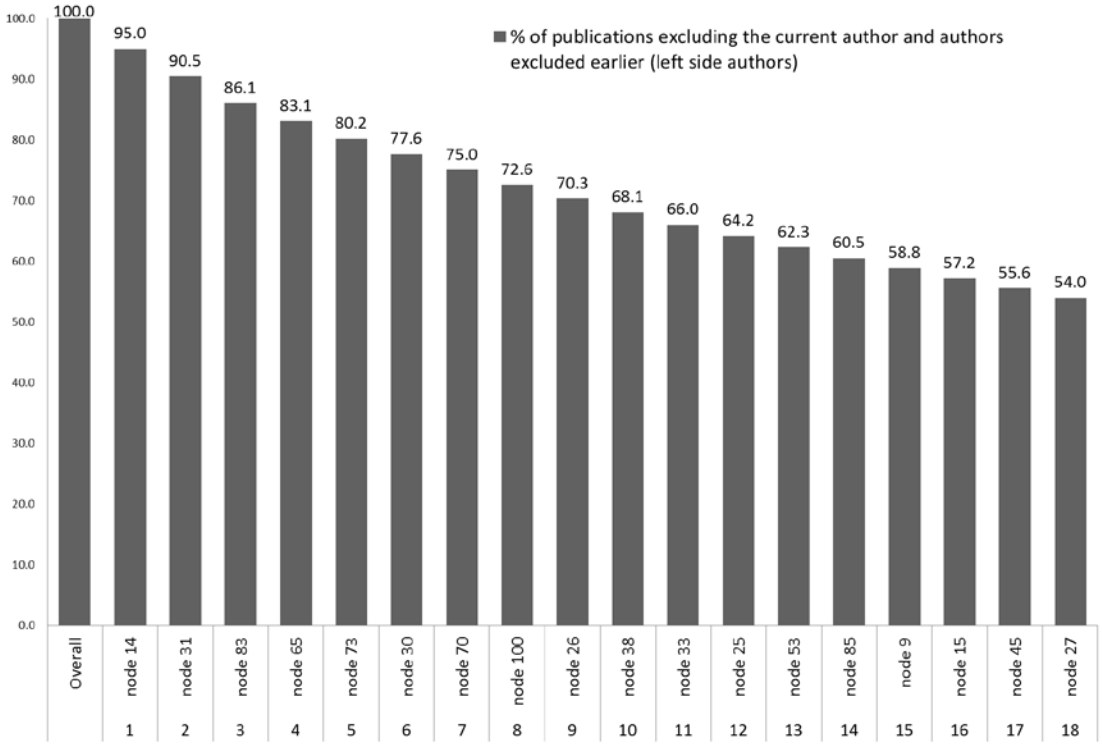

Figure 22. NHH publications based on the sequential deletion of the faculty members who have at least 20 publications registered in the *ISI Web of Science*

Table 9. Publications by faculty members at BI

	Faculty	number of publications	Overall after exclusion	% out of overall publications	Overall % after exclusion
1	node 166	70	1225	5.4	94.6
2	node 223	59	1166	4.6	90.0
3	node 100	42	1124	3.2	86.8
4	node 83	38	1086	2.9	83.9
5	node 185	38	1048	2.9	80.9
6	node 184	29	1019	2.2	78.7
7	node 67	28	991	2.2	76.5
8	node 138	28	963	2.2	74.4
9	node 171	28	935	2.2	72.2
10	node 180	27	908	2.1	70.1
11	node 181	25	883	1.9	68.2
12	node 148	23	860	1.8	66.4
13	node 120	22	838	1.7	64.7
14	node 131	21	817	1.6	63.1
15	node 94	20	797	1.5	61.5
16	node 43	20	777	1.5	60.0

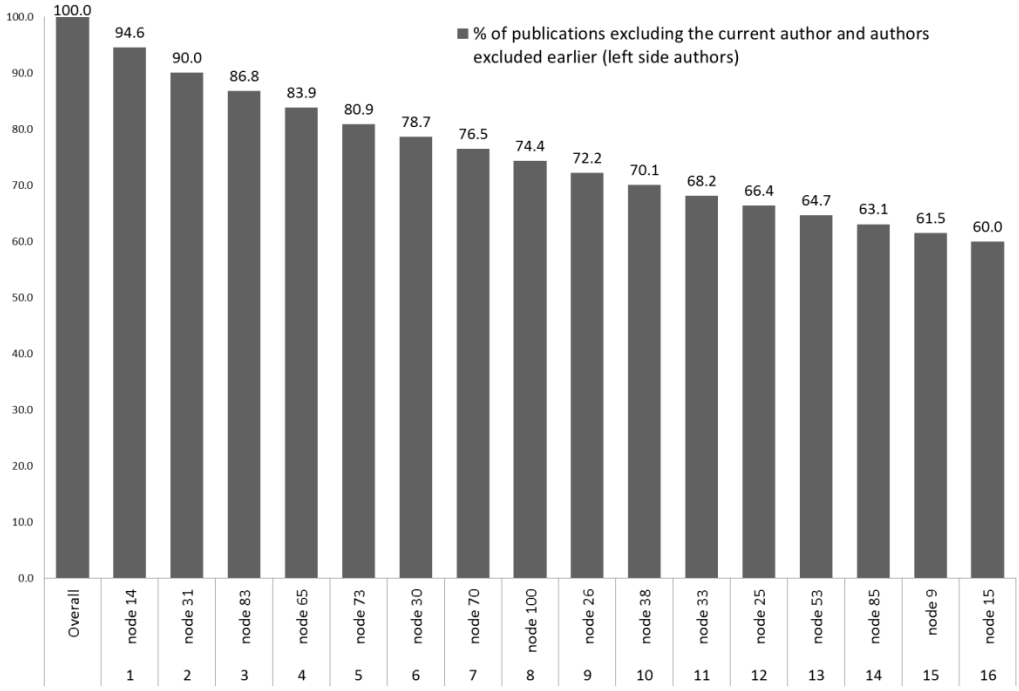

Figure 23. Overall BI publications based on the sequential deletion of the faculty members who have at least 20 publications registered in the *ISI Web of Science*

Also it is remarkable that only a few faculty members generate the majority of international publications in both schools.

7. CONCLUSION

In this article we analyzed the NHH and BI co-authorship networks based on the information retrieved from *ISI Web of Science*. We covered the publications in the period 1950 – Spring, 2014 for the current faculty members. The results were represented in tabular and graphical formats. The diversified representation of the overall co-authorship was combined with the information regarding the number of publications by each faculty member.

Next, we analyzed the strongly connected research groups (i.e., cliques) on the interdepartmental level. The importance of this analysis is based on the necessity of detection and clear representation of the research groups and their interactions between each other. The analysis of spanning trees and forests helped to visualize the spread of the research interests by the faculty members from different departments over the whole NHH and BI co-authorship networks. In fact, we draw a clear picture of how faculty members from different departments are connected to each other in the diversified "chains" of varying research interests.

We analyzed the international co-authorship for the NHH and BI researchers without splitting the faculty members according to their departments' affiliations. Based on this analysis we made the representation of the faculty members' international relations (based on the *ISI Web of Science*). Also, it helped to detect the groups of faculty members that make the most contribution to the international research collaboration.

Finally, we analyzed the research activity of the NHH and BI faculty members based on the number of publications registered in the *ISI Web of Science.*

It is important to notice that the results regarding the publications counted in the given research were retrieved in different periods of Spring, 2014. This is due to the fact that the process of extracting, filtering and systemizing the required information is time consuming. Therefore, we would like to specify that the retrieved information could be updated and changed since its last extraction. The detailed information in tabular format is available upon request. Also, we would like to notice that the centralities analysis is left to the reader depending on specific interests.

We assume that the given research might be helpful for an understanding of what is done by the NHH and BI faculty members in terms of scientific research. However, since we have used only one source, the *ISI Web of Science*, the analysis should be complemented by the use of other sources such as *SCOPUS* and *Google Scholar* to get a more complete view of the scientific research activities of the NHH and BI faculty members. In order to make such an analysis doable all faculty members must be registered in *Google Scholar* with an open profile. In order to use an analysis of this type as a tool for the further planning of the research activities and as a tool for strategic development, the registrations of research activities should be updated on a regular basis.

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APPENDIX A. *Overall international coathorship by faculty members at NHH*

	Faculty	number of coauthorship	Overall after exclusion	% out of overall coauthorship	Overall % after exclusion			Faculty	number of coauthorship	Overall after exclusion	% out of overall coauthorship	Overall % after exclusion
1	node 38	55	738	6.9	93.1		40	node 23	5	124	0.6	15.6
2	node 14	54	684	6.8	86.3		41	node 51	5	119	0.6	15.0
3	node 83	50	634	6.3	79.9		42	node 68	5	114	0.6	14.4
4	node 105	46	588	5.8	74.1		43	node 102	5	109	0.6	13.7
5	node 65	41	547	5.2	69.0		44	node 117	5	104	0.6	13.1
6	node 31	32	515	4.0	64.9		45	node 129	5	99	0.6	12.5
7	node 27	27	488	3.4	61.5		46	node 138	5	94	0.6	11.9
8	node 40	25	463	3.2	58.4		47	node 17	4	90	0.5	11.3
9	node 77	24	439	3.0	55.4		48	node 42	4	86	0.5	10.8
10	node 11	21	418	2.6	52.7		49	node 56	4	82	0.5	10.3
11	node 26	21	397	2.6	50.1		50	node 69	4	78	0.5	9.8
12	node 73	20	377	2.5	47.5		51	node 112	4	74	0.5	9.3
13	node 106	20	357	2.5	45.0		52	node 125	4	70	0.5	8.8
14	node 8	18	339	2.3	42.7		53	node 34	3	67	0.4	8.4
15	node 16	14	325	1.8	41.0		54	node 36	3	64	0.4	8.1
16	node 4	11	314	1.4	39.6		55	node 54	3	61	0.4	7.7
17	node 15	11	303	1.4	38.2		56	node 76	3	58	0.4	7.3
18	node 25	11	292	1.4	36.8		57	node 101	3	55	0.4	6.9
19	node 30	11	281	1.4	35.4		58	node 108	3	52	0.4	6.6
20	node 53	11	270	1.4	34.0		59	node 142	3	49	0.4	6.2
21	node 55	10	260	1.3	32.8		60	node 6	2	47	0.3	5.9
22	node 111	10	250	1.3	31.5		61	node 13	2	45	0.3	5.7
23	node 39	9	241	1.1	30.4		62	node 21	2	43	0.3	5.4
24	node 61	9	232	1.1	29.3		63	node 22	2	41	0.3	5.2
25	node 3	8	224	1.0	28.2		64	node 35	2	39	0.3	4.9
26	node 50	8	216	1.0	27.2		65	node 44	2	37	0.3	4.7
27	node 62	8	208	1.0	26.2		66	node 45	2	35	0.3	4.4
28	node 85	8	200	1.0	25.2		67	node 57	2	33	0.3	4.2
29	node 109	8	192	1.0	24.2		68	node 58	2	31	0.3	3.9
30	node 46	7	185	0.9	23.3		69	node 60	2	29	0.3	3.7
31	node 126	7	178	0.9	22.4		70	node 70	2	27	0.3	3.4
32	node 132	7	171	0.9	21.6		71	node 86	2	25	0.3	3.2
33	node 9	6	165	0.8	20.8		72	node 87	2	23	0.3	2.9
34	node 66	6	159	0.8	20.1		73	node 114	2	21	0.3	2.6
35	node 78	6	153	0.8	19.3		74	node 115	2	19	0.3	2.4
36	node 82	6	147	0.8	18.5		75	node 143	2	17	0.3	2.1
37	node 100	6	141	0.8	17.8		76	node 1	1	16	0.1	2.0
38	node 119	6	135	0.8	17.0		77	node 7	1	15	0.1	1.9
39	node 130	6	129	0.8	16.3		78	node 19	1	14	0.1	1.8

APPENDIX A. *Continued*

	Faculty	number of coauthorship	Overall after exclusion	% out of overall coauthorship	Overall % after exclusion			Faculty	number of coauthorship	Overall after exclusion	% out of overall coauthorship	Overall % after exclusion
79	node 33	1	13	0.1	1.6		118	node 89	0	0	0.0	0.0
80	node 37	1	12	0.1	1.5		119	node 90	0	0	0.0	0.0
81	node 59	1	11	0.1	1.4		120	node 91	0	0	0.0	0.0
82	node 67	1	10	0.1	1.3		121	node 94	0	0	0.0	0.0
83	node 71	1	9	0.1	1.1		122	node 97	0	0	0.0	0.0
84	node 72	1	8	0.1	1.0		123	node 99	0	0	0.0	0.0
85	node 92	1	7	0.1	0.9		124	node 103	0	0	0.0	0.0
86	node 93	1	6	0.1	0.8		125	node 104	0	0	0.0	0.0
87	node 95	1	5	0.1	0.6		126	node 107	0	0	0.0	0.0
88	node 96	1	4	0.1	0.5		127	node 110	0	0	0.0	0.0
89	node 98	1	3	0.1	0.4		128	node 113	0	0	0.0	0.0
90	node 116	1	2	0.1	0.3		129	node 120	0	0	0.0	0.0
91	node 118	1	1	0.1	0.1		130	node 121	0	0	0.0	0.0
92	node 122	1	0	0.1	0.0		131	node 123	0	0	0.0	0.0
93	node 2	0	0	0.0	0.0		132	node 124	0	0	0.0	0.0
94	node 5	0	0	0.0	0.0		133	node 127	0	0	0.0	0.0
95	node 10	0	0	0.0	0.0		134	node 128	0	0	0.0	0.0
96	node 12	0	0	0.0	0.0		135	node 131	0	0	0.0	0.0
97	node 18	0	0	0.0	0.0		136	node 133	0	0	0.0	0.0
98	node 20	0	0	0.0	0.0		137	node 134	0	0	0.0	0.0
99	node 24	0	0	0.0	0.0		138	node 135	0	0	0.0	0.0
100	node 28	0	0	0.0	0.0		139	node 136	0	0	0.0	0.0
101	node 29	0	0	0.0	0.0		140	node 137	0	0	0.0	0.0
102	node 32	0	0	0.0	0.0		141	node 139	0	0	0.0	0.0
103	node 41	0	0	0.0	0.0		142	node 140	0	0	0.0	0.0
104	node 43	0	0	0.0	0.0		143	node 141	0	0	0.0	0.0
105	node 47	0	0	0.0	0.0		144	node 144	0	0	0.0	0.0
106	node 48	0	0	0.0	0.0		145	node 145	0	0	0.0	0.0
107	node 49	0	0	0.0	0.0		146	node 146	0	0	0.0	0.0
108	node 52	0	0	0.0	0.0		147	node 147	0	0	0.0	0.0
109	node 63	0	0	0.0	0.0		148	node 148	0	0	0.0	0.0
110	node 64	0	0	0.0	0.0		149	node 149	0	0	0.0	0.0
111	node 74	0	0	0.0	0.0		150	node 150	0	0	0.0	0.0
112	node 75	0	0	0.0	0.0		151	node 151	0	0	0.0	0.0
113	node 79	0	0	0.0	0.0		152	node 152	0	0	0.0	0.0
114	node 80	0	0	0.0	0.0		153	node 153	0	0	0.0	0.0
115	node 81	0	0	0.0	0.0		154	node 154	0	0	0.0	0.0
116	node 84	0	0	0.0	0.0		155	node 155	0	0	0.0	0.0
117	node 88	0	0	0.0	0.0		156	node 156	0	0	0.0	0.0

APPENDIX B. *Overall international coathorship by faculty members at BI*

	Faculty	number of coauthorship	Overall after exclusion	% out of overall coauthorship	Overall % after exclusion		Faculty	number of coauthorship	Overall after exclusion	% out of overall coauthorship	Overall % after exclusion
1	node 223	127	876	12.7	87.3	64	node 66	3	66	0.3	6.6
2	node 184	66	810	6.6	80.8	65	node 93	3	63	0.3	6.3
3	node 83	40	770	4.0	76.8	66	node 102	3	60	0.3	6.0
4	node 67	39	731	3.9	72.9	67	node 127	3	57	0.3	5.7
5	node 181	39	692	3.9	69.0	68	node 198	3	54	0.3	5.4
6	node 192	36	656	3.6	65.4	69	node 201	3	51	0.3	5.1
7	node 185	35	621	3.5	61.9	70	node 207	3	48	0.3	4.8
8	node 138	30	591	3.0	58.9	71	node 219	3	45	0.3	4.5
9	node 238	28	563	2.8	56.1	72	node 27	2	43	0.2	4.3
10	node 38	25	538	2.5	53.6	73	node 72	2	41	0.2	4.1
11	node 243	24	514	2.4	51.2	74	node 106	2	39	0.2	3.9
12	node 79	23	491	2.3	49.0	75	node 108	2	37	0.2	3.7
13	node 120	22	469	2.2	46.8	76	node 129	2	35	0.2	3.5
14	node 178	22	447	2.2	44.6	77	node 140	2	33	0.2	3.3
15	node 189	19	428	1.9	42.7	78	node 154	2	31	0.2	3.1
16	node 231	19	409	1.9	40.8	79	node 159	2	29	0.2	2.9
17	node 174	18	391	1.8	39.0	80	node 162	2	27	0.2	2.7
18	node 94	15	376	1.5	37.5	81	node 217	2	25	0.2	2.5
19	node 122	14	362	1.4	36.1	82	node 235	2	23	0.2	2.3
20	node 148	13	349	1.3	34.8	83	node 239	2	21	0.2	2.1
21	node 103	11	338	1.1	33.7	84	node 244	2	19	0.2	1.9
22	node 167	11	327	1.1	32.6	85	node 252	2	17	0.2	1.7
23	node 175	11	316	1.1	31.5	86	node 10	1	16	0.1	1.6
24	node 211	10	306	1.0	30.5	87	node 42	1	15	0.1	1.5
25	node 220	10	296	1.0	29.5	88	node 56	1	14	0.1	1.4
26	node 240	10	286	1.0	28.5	89	node 77	1	13	0.1	1.3
27	node 43	9	277	0.9	27.6	90	node 100	1	12	0.1	1.2
28	node 194	9	268	0.9	26.7	91	node 104	1	11	0.1	1.1
29	node 212	9	259	0.9	25.8	92	node 112	1	10	0.1	1.0
30	node 228	9	250	0.9	24.9	93	node 133	1	9	0.1	0.9
31	node 233	9	241	0.9	24.0	94	node 173	1	8	0.1	0.8
32	node 59	8	233	0.8	23.2	95	node 179	1	7	0.1	0.7
33	node 96	8	225	0.8	22.4	96	node 186	1	6	0.1	0.6
34	node 113	8	217	0.8	21.6	97	node 216	1	5	0.1	0.5
35	node 166	8	209	0.8	20.8	98	node 218	1	4	0.1	0.4
36	node 224	8	201	0.8	20.0	99	node 222	1	3	0.1	0.3
37	node 246	8	193	0.8	19.2	100	node 232	1	2	0.1	0.2
38	node 37	7	186	0.7	18.5	101	node 241	1	1	0.1	0.1
39	node 200	7	179	0.7	17.8	102	node 249	1	0	0.1	0.0
40	node 132	6	173	0.6	17.2	103	node 1	0	0	0.0	0.0
41	node 172	6	167	0.6	16.7	104	node 2	0	0	0.0	0.0
42	node 234	6	161	0.6	16.1	105	node 3	0	0	0.0	0.0
43	node 237	6	155	0.6	15.5	106	node 4	0	0	0.0	0.0
44	node 99	5	150	0.5	15.0	107	node 5	0	0	0.0	0.0
45	node 118	5	145	0.5	14.5	108	node 6	0	0	0.0	0.0
46	node 119	5	140	0.5	14.0	109	node 7	0	0	0.0	0.0
47	node 145	5	135	0.5	13.5	110	node 8	0	0	0.0	0.0
48	node 171	5	130	0.5	13.0	111	node 9	0	0	0.0	0.0
49	node 203	5	125	0.5	12.5	112	node 12	0	0	0.0	0.0
50	node 210	5	120	0.5	12.0	113	node 13	0	0	0.0	0.0
51	node 229	5	115	0.5	11.5	114	node 14	0	0	0.0	0.0
52	node 36	4	111	0.4	11.1	115	node 15	0	0	0.0	0.0
53	node 98	4	107	0.4	10.7	116	node 16	0	0	0.0	0.0
54	node 101	4	103	0.4	10.3	117	node 17	0	0	0.0	0.0
55	node 130	4	99	0.4	9.9	118	node 18	0	0	0.0	0.0
56	node 155	4	95	0.4	9.5	119	node 19	0	0	0.0	0.0
57	node 165	4	91	0.4	9.1	120	node 20	0	0	0.0	0.0
58	node 182	4	87	0.4	8.7	121	node 21	0	0	0.0	0.0
59	node 215	4	83	0.4	8.3	122	node 22	0	0	0.0	0.0
60	node 242	4	79	0.4	7.9	123	node 23	0	0	0.0	0.0
61	node 247	4	75	0.4	7.5	124	node 24	0	0	0.0	0.0
62	node 11	3	72	0.3	7.2	125	node 25	0	0	0.0	0.0
63	node 29	3	69	0.3	6.9	126	node 26	0	0	0.0	0.0

APPENDIX B. *Continued*

	Faculty	number of coauthorship	Overall after exclusion	% out of overall coauthorship	Overall % after exclusion		Faculty	number of coauthorship	Overall after exclusion	% out of overall coauthorship	Overall % after exclusion
127	node 28	0	0	0.0	0.0	190	node 123	0	0	0.0	0.0
128	node 30	0	0	0.0	0.0	191	node 124	0	0	0.0	0.0
129	node 31	0	0	0.0	0.0	192	node 125	0	0	0.0	0.0
130	node 32	0	0	0.0	0.0	193	node 126	0	0	0.0	0.0
131	node 33	0	0	0.0	0.0	194	node 128	0	0	0.0	0.0
132	node 34	0	0	0.0	0.0	195	node 131	0	0	0.0	0.0
133	node 35	0	0	0.0	0.0	196	node 134	0	0	0.0	0.0
134	node 39	0	0	0.0	0.0	197	node 135	0	0	0.0	0.0
135	node 40	0	0	0.0	0.0	198	node 136	0	0	0.0	0.0
136	node 41	0	0	0.0	0.0	199	node 137	0	0	0.0	0.0
137	node 44	0	0	0.0	0.0	200	node 139	0	0	0.0	0.0
138	node 45	0	0	0.0	0.0	201	node 141	0	0	0.0	0.0
139	node 46	0	0	0.0	0.0	202	node 142	0	0	0.0	0.0
140	node 47	0	0	0.0	0.0	203	node 143	0	0	0.0	0.0
141	node 48	0	0	0.0	0.0	204	node 144	0	0	0.0	0.0
142	node 49	0	0	0.0	0.0	205	node 146	0	0	0.0	0.0
143	node 50	0	0	0.0	0.0	206	node 147	0	0	0.0	0.0
144	node 51	0	0	0.0	0.0	207	node 149	0	0	0.0	0.0
145	node 52	0	0	0.0	0.0	208	node 150	0	0	0.0	0.0
146	node 53	0	0	0.0	0.0	209	node 151	0	0	0.0	0.0
147	node 54	0	0	0.0	0.0	210	node 152	0	0	0.0	0.0
148	node 55	0	0	0.0	0.0	211	node 153	0	0	0.0	0.0
149	node 57	0	0	0.0	0.0	212	node 156	0	0	0.0	0.0
150	node 58	0	0	0.0	0.0	213	node 157	0	0	0.0	0.0
151	node 60	0	0	0.0	0.0	214	node 158	0	0	0.0	0.0
152	node 61	0	0	0.0	0.0	215	node 160	0	0	0.0	0.0
153	node 62	0	0	0.0	0.0	216	node 161	0	0	0.0	0.0
154	node 63	0	0	0.0	0.0	217	node 163	0	0	0.0	0.0
155	node 64	0	0	0.0	0.0	218	node 164	0	0	0.0	0.0
156	node 65	0	0	0.0	0.0	219	node 168	0	0	0.0	0.0
157	node 68	0	0	0.0	0.0	220	node 169	0	0	0.0	0.0
158	node 69	0	0	0.0	0.0	221	node 170	0	0	0.0	0.0
159	node 70	0	0	0.0	0.0	222	node 176	0	0	0.0	0.0
160	node 71	0	0	0.0	0.0	223	node 177	0	0	0.0	0.0
161	node 73	0	0	0.0	0.0	224	node 180	0	0	0.0	0.0
162	node 74	0	0	0.0	0.0	225	node 183	0	0	0.0	0.0
163	node 75	0	0	0.0	0.0	226	node 187	0	0	0.0	0.0
164	node 76	0	0	0.0	0.0	227	node 188	0	0	0.0	0.0
165	node 78	0	0	0.0	0.0	228	node 190	0	0	0.0	0.0
166	node 80	0	0	0.0	0.0	229	node 191	0	0	0.0	0.0
167	node 81	0	0	0.0	0.0	230	node 193	0	0	0.0	0.0
168	node 82	0	0	0.0	0.0	231	node 195	0	0	0.0	0.0
169	node 84	0	0	0.0	0.0	232	node 196	0	0	0.0	0.0
170	node 85	0	0	0.0	0.0	233	node 197	0	0	0.0	0.0
171	node 86	0	0	0.0	0.0	234	node 199	0	0	0.0	0.0
172	node 87	0	0	0.0	0.0	235	node 202	0	0	0.0	0.0
173	node 88	0	0	0.0	0.0	236	node 204	0	0	0.0	0.0
174	node 89	0	0	0.0	0.0	237	node 205	0	0	0.0	0.0
175	node 90	0	0	0.0	0.0	238	node 206	0	0	0.0	0.0
176	node 91	0	0	0.0	0.0	239	node 208	0	0	0.0	0.0
177	node 92	0	0	0.0	0.0	240	node 209	0	0	0.0	0.0
178	node 95	0	0	0.0	0.0	241	node 213	0	0	0.0	0.0
179	node 97	0	0	0.0	0.0	242	node 214	0	0	0.0	0.0
180	node 105	0	0	0.0	0.0	243	node 221	0	0	0.0	0.0
181	node 107	0	0	0.0	0.0	244	node 225	0	0	0.0	0.0
182	node 109	0	0	0.0	0.0	245	node 226	0	0	0.0	0.0
183	node 110	0	0	0.0	0.0	246	node 227	0	0	0.0	0.0
184	node 111	0	0	0.0	0.0	247	node 230	0	0	0.0	0.0
185	node 114	0	0	0.0	0.0	248	node 236	0	0	0.0	0.0
186	node 115	0	0	0.0	0.0	249	node 245	0	0	0.0	0.0
187	node 116	0	0	0.0	0.0	250	node 248	0	0	0.0	0.0
188	node 117	0	0	0.0	0.0	251	node 250	0	0	0.0	0.0
189	node 121	0	0	0.0	0.0	252	node 251	0	0	0.0	0.0

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