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Discussion paper

The Coauthorship Network Analysis of the Norwegian School of Economics

BY

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THE COAUTHORSHIP NETWORK ANALYSIS OF THE NORWEGIAN SCHOOL OF ECONOMICS

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Abstract

We construct the coauthorship network based on the scientific collaboration between the faculty members at the Norwegian School of Economics (NHH) and based on their international academic publication experience. The network structure is based on the NHH faculties' publications recognized by the ISI Web of Science for the period 1950 – Spring, 2014. The given network covers the publication activities of the NHH faculty members (over six departments) based on the information retrieved from the ISI Web of Science in Spring, 2014. In this paper we analyse the constructed coauthorship network in different aspects of the theory of social networks analysis.

Keywords: coauthorship networks, social networks analysis.

1. INTRODUCTION

Social networks analysis (SNA) is a powerful tool to analyse the interpersonal relations and different types of cooperation between the variety of social groups such as the 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 it takes into consideration the multifactorial social aspects of relations (Carrington, Scott, & Wasserman, 2005).

In this study we build the NHH social network based on the coauthorship relations between the faculty members. The resulted NHH coauthorship network is constructed based on the information retrieved from *the ISI Web of Science* as of March – April, 2014 (ISI Web of Science, 2014). *ISI Web of Science* provides the online scientific citation indexing service of the highly qualified journals from cross-disciplinary areas. It is important to notice that we use *the ISI Web of Science* as the only source to retrieve the information regarding the NHH faculty members' publications in the period 1950 – Spring, 2014. The resulted NHH coauthorship network covers six NHH 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 coauthorship network's 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 also we show the external publications with authors that are not affiliated with NHH. These "external" coauthors are grouped into the country-nodes. For example, if "external" author A and "external" author B specify their affiliation with country N in their publications then both A and B are grouped into one node N. As the result, we show the research cooperation of the NHH faculty members on the international level.

In section 2 we show the position of each faculty member within the NHH coauthorship network including the internal departmental, interdepartmental and external coauthorship relations. Also, we provide the number of publications, which are done by each faculty member. The results are represented in tabular and graphical formats.

Section 3 is devoted to the analysis of coauthorship cliques between the faculty members. Since cliques (Hanneman & Riddle, 2005) correspond to the groups of faculty members that have strong coauthorship relations, we analyze the NHH coauthorship network to detect such groups (i.e., cliques) and their collaboration with other cliques or single faculty members.

In section 4 we analyze the NHH coauthorship network based on the spanning trees' detection (West, 2001). Spanning tree's analysis is the way to understand the spread of the research interests over the whole NHH coauthorship networks. Moreover, due to the fact that the NHH coauthorship network is represented by the disconnected graph, we analyze it in terms of the departmental and interdepartmental spanning forests (Bollobás, 1998).

In section 5 we analyze the international coauthorship. The analysis is based on the investigation of how many persons (i.e., nodes) at NHH coauthorship network should be deleted in order for the international coauthorship to be vanishing.

The overall publications-based analysis is represented in section 6. Specifically, we analyze the contribution of the most published faculty members to the overall NHH research activity.

2. PERSONAL INTERNAL, EXTERNAL AND OVERALL COAUTHORSHIPS

For each faculty member we analyse the number of departmental, interdepartmental, and external (i.e., not affiliated with NHH) collaborations and the number of the published papers based on *the ISI Web of Science*. We provide the details for each department in tabular and graph-based formats.

In Tables 1-7 and in Figures 1-19 we provide the information regarding the internal, interdepartmental and external coauthorship for each faculty member. The values given in Tables 1-7 correspond to the number of coauthors and to the number of publications for each faculty member. In Figures 1, 4, 7, 10, 13, and 16 we provide the information regarding the number of coauthors versus the number of publications for each faculty member.

The networks of the internal (i.e., departmental) coauthorship are represented in Figures 2, 5, 8, 11, 14, 17 for each department. The overall departmental networks that include the internal, interdepartmental and external coauthorship are represented in Figures 3, 6, 9, 12, 15, and 18.

2.1 Department of Business and Management Science

Table 1. Coauthorship and the number of publications by persons

Faculty	Coauthorship				Number of publications
	Internal	Interdepart.	external	Total	
node 1	7	1	2	10	7
node 2	2	0	4	6	4
node 3	3	0	8	11	6
node 4	5	0	13	18	7
node 5	0	0	0	0	0
node 6	0	0	2	2	2
node 7	0	0	3	3	3
node 8	0	0	29	29	19
node 9	1	19	14	34	21
node 10	4	1	3	8	6
node 11	0	0	21	21	6
node 12	0	0	0	0	1
node 13	0	0	2	2	1
node 14	22	1	86	109	64
node 15	0	0	13	13	21
node 16	4	0	14	18	4
node 17	0	0	4	4	5
node 18	0	1	3	4	3
node 19	0	0	3	3	4
node 20	0	0	0	0	1
node 21	0	1	10	11	6
node 22	10	0	3	13	7
node 23	4	0	23	27	31
node 24	3	0	1	4	2
node 25	27	0	13	40	24
node 26	1	11	28	40	29
node 27	15	0	35	50	20
node 28	6	0	6	12	9
node 29	4	1	2	7	4
node 30	17	1	48	66	33
node 31	2	0	70	72	58
node 32	0	0	0	0	0
node 33	1	1	5	7	26

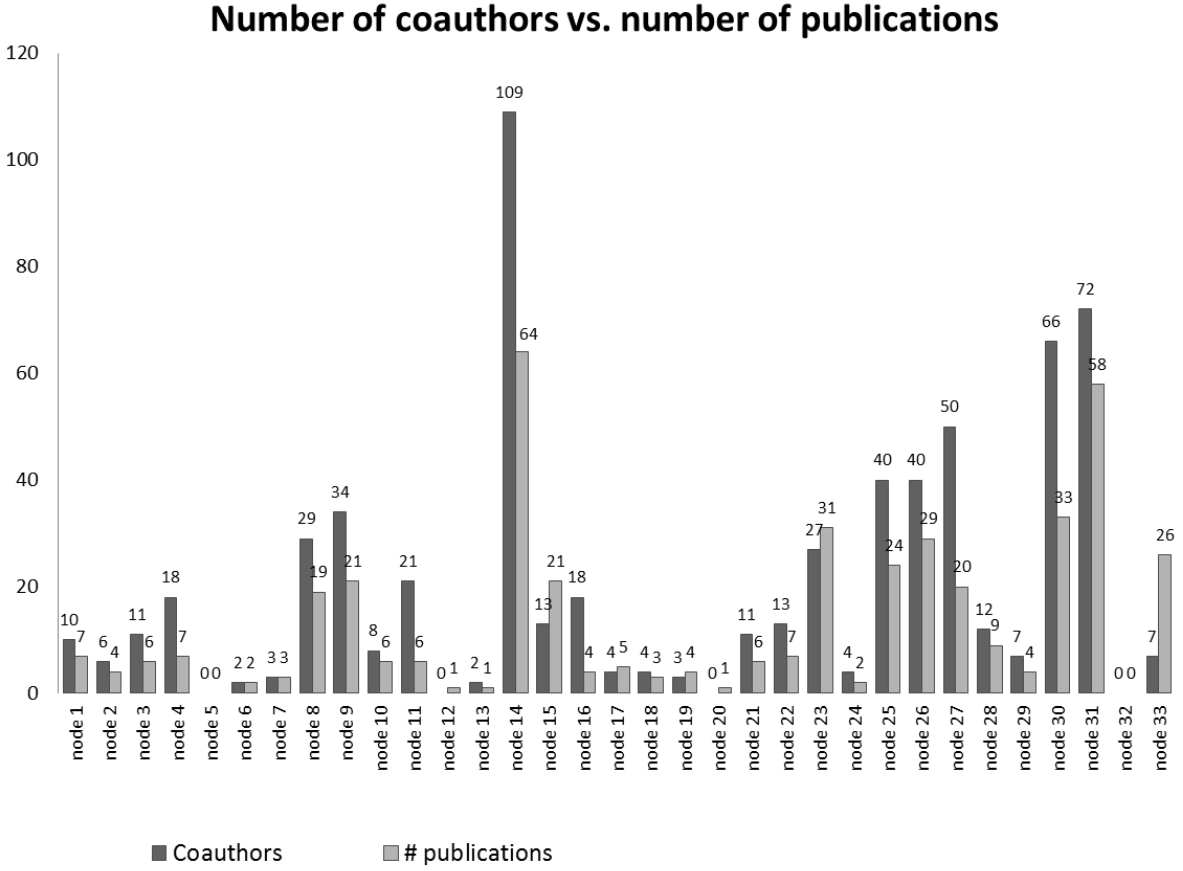


Figure 1. Department of Business and Management Science:
Number of coauthors vs. number of publications

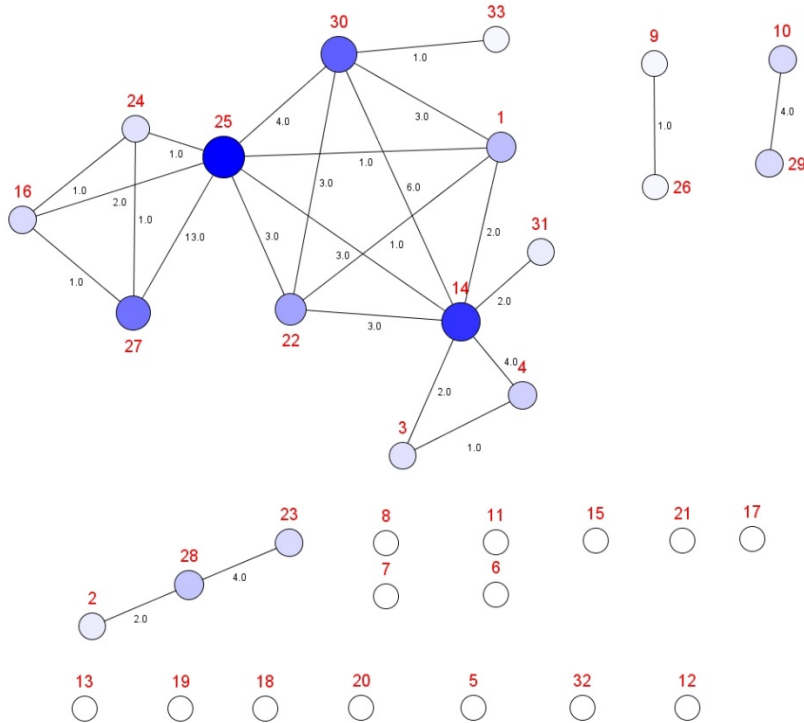


Figure 2. Department of Business and Management Science – the internal coauthorship network

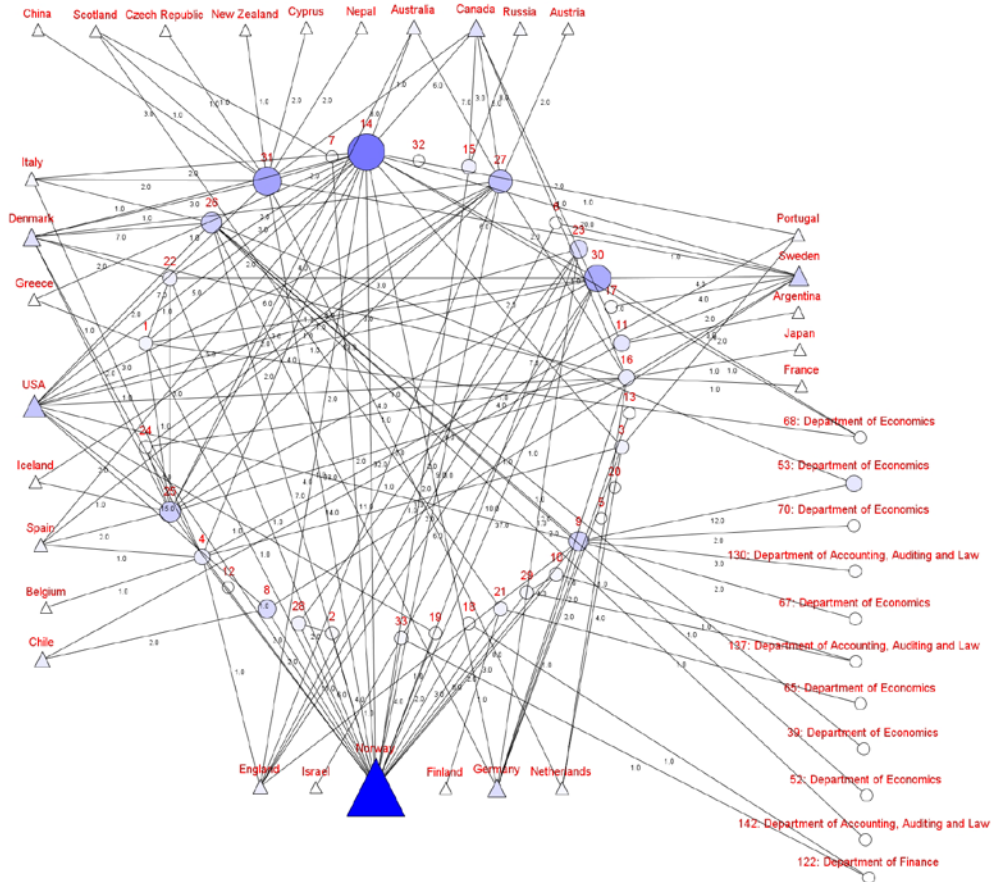


Figure 3. Department of Business and Management Science – the overall coauthorship network

2.2 Department of Economics

Table 2. Coauthorship and the number of publications by persons

Faculty	Coauthorship				Number of publications
	internal	interdep.	external	total	
node 34	6	0	6	12	8
node 35	0	0	2	2	4
node 36	0	0	5	5	9
node 37	2	0	1	3	1
node 38	1	0	58	59	29
node 39	5	1	10	16	19
node 40	1	0	29	30	16
node 41	1	0	7	8	6
node 42	0	0	4	4	12
node 43	0	0	0	0	1
node 44	0	0	2	2	1
node 45	31	0	11	42	21
node 46	0	0	7	7	5
node 47	0	0	0	0	1
node 48	0	0	0	0	1
node 49	0	0	1	1	7
node 50	4	0	12	16	14
node 51	0	0	6	6	5
node 52	0	1	0	1	2
node 53	6	19	19	44	24
node 54	0	0	6	6	13
node 55	0	0	14	14	11
node 56	0	0	5	5	6
node 57	0	0	2	2	1
node 58	5	0	4	9	11
node 59	0	0	1	1	2
node 60	5	0	29	34	18
node 61	2	0	10	12	13
node 62	0	0	8	8	10
node 63	0	0	0	0	0
node 64	0	0	0	0	4
node 65	9	1	66	76	38
node 66	0	0	7	7	10
node 67	8	2	5	15	12
node 68	1	4	6	11	8
node 69	23	0	10	33	11
node 70	15	2	25	42	33
node 71	0	0	3	3	8
node 72	0	0	9	9	10
node 73	32	0	33	65	37
node 74	0	0	1	1	2
node 75	0	0	2	2	5
node 76	1	0	10	11	7

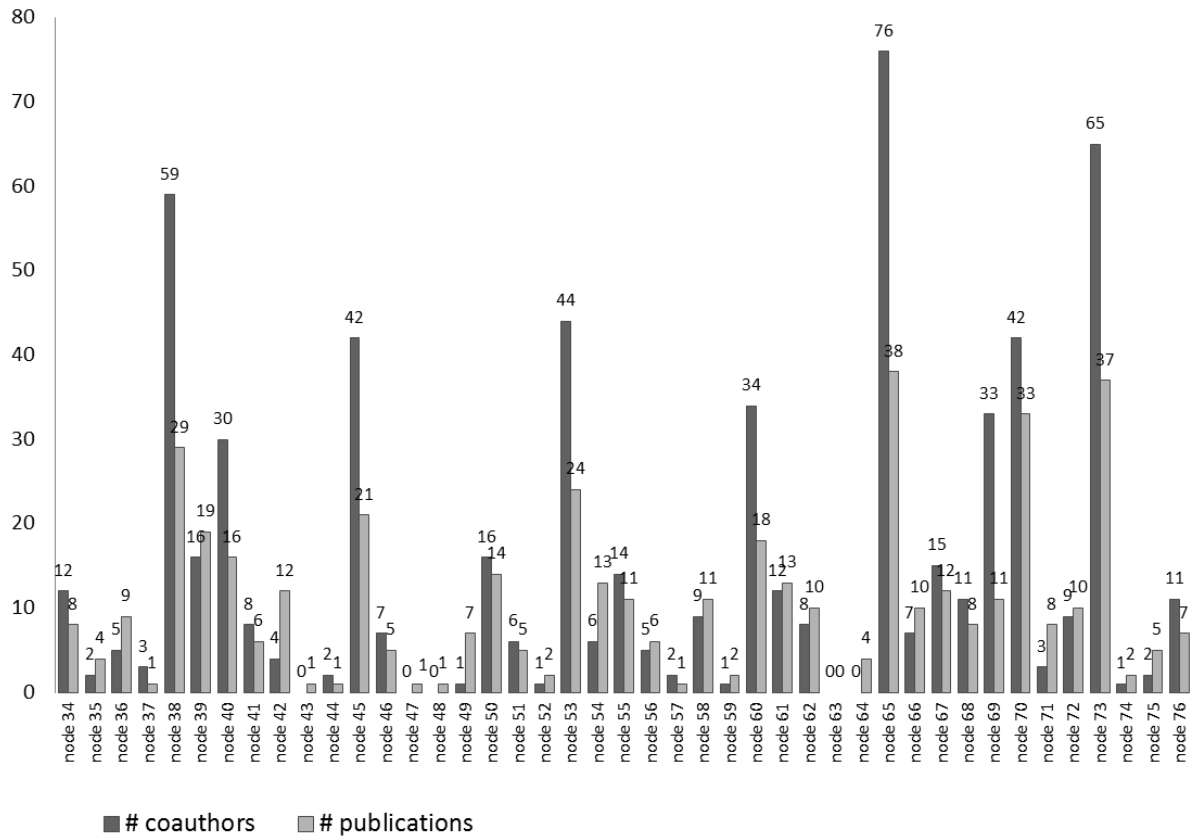


Figure 4. Department of Economics:
number of coauthors vs. number of publications

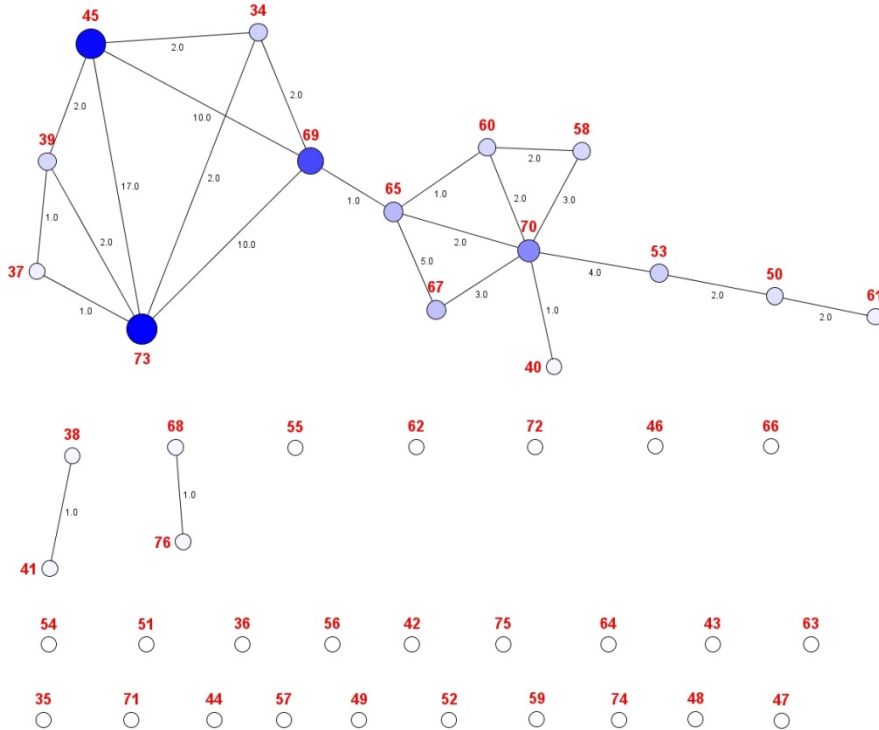


Figure 5. Department of Economics – the internal coauthorship network

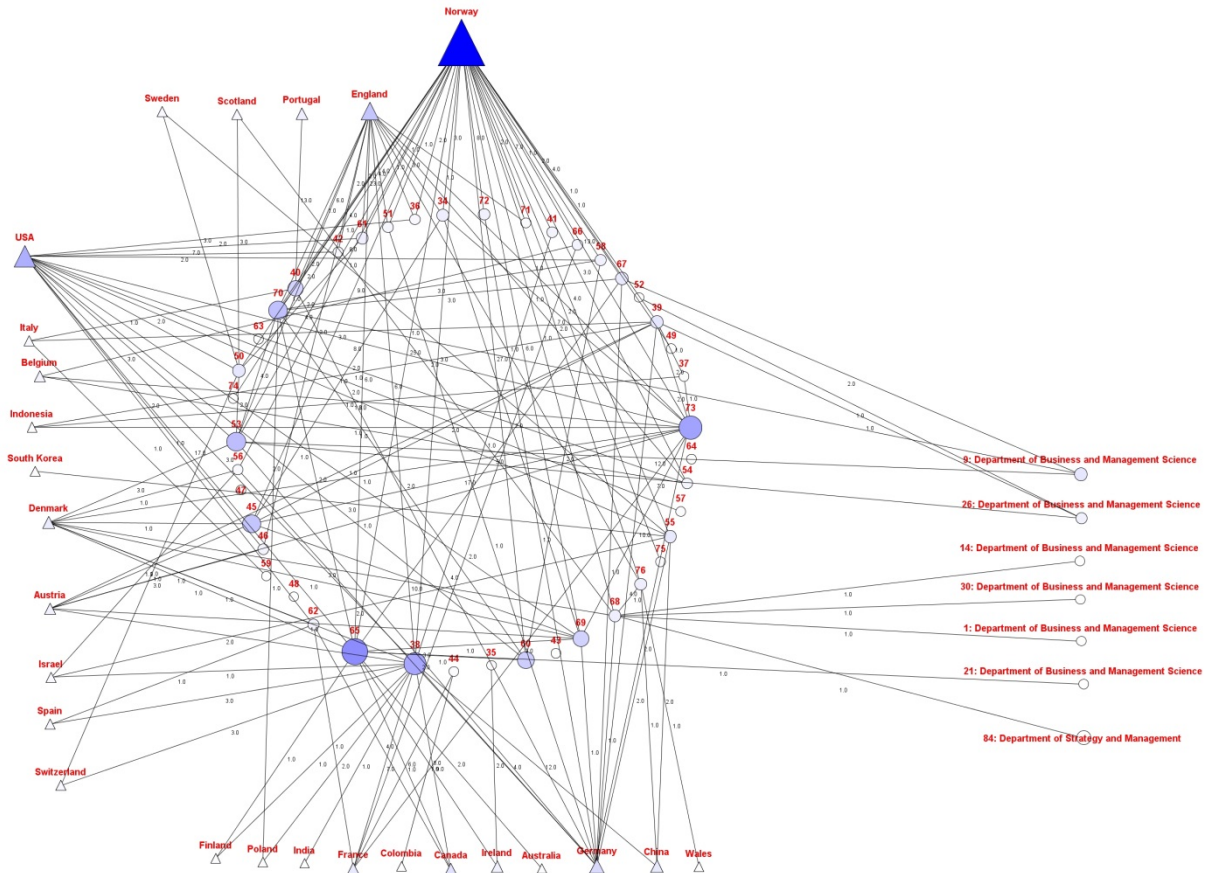


Figure 6. Department of Economics – the overall coauthorship network

2.3 Department of Strategy and Management

Table 3. Coauthorship and the number of publications by persons

Faculty	Coauthorship				Number of publications
	internal	Interdep.	external	total	
node 77	0	0	30	30	16
node 78	4	0	9	13	8
node 79	0	0	0	0	0
node 80	0	0	0	0	0
node 81	3	0	3	6	6
node 82	6	0	6	12	9
node 83	6	0	51	57	56
node 84	0	1	4	5	5
node 85	2	0	24	26	23
node 86	2	0	23	25	14
node 87	0	0	8	8	7
node 88	0	0	6	6	5
node 89	0	0	4	4	3
node 90	0	0	0	0	0
node 91	0	0	0	0	0
node 92	0	0	2	2	2
node 93	0	0	13	13	7
node 94	2	0	9	11	5
node 95	0	0	4	4	3
node 96	0	0	4	4	3
node 97	3	0	5	8	9
node 98	6	0	7	13	8
node 99	0	0	0	0	1
node 100	0	0	17	17	14
node 101	6	0	5	11	9
node 102	1	0	6	7	3
node 103	0	0	0	0	0
node 104	0	0	0	0	0
node 105	6	0	54	60	10
node 106	0	0	32	32	15
node 107	0	0	0	0	0
node 108	5	1	7	13	9
node 109	6	0	14	20	14
node 110	0	0	0	0	0
node 111	6	0	16	22	10
node 112	2	0	13	15	9
node 113	0	0	1	1	5

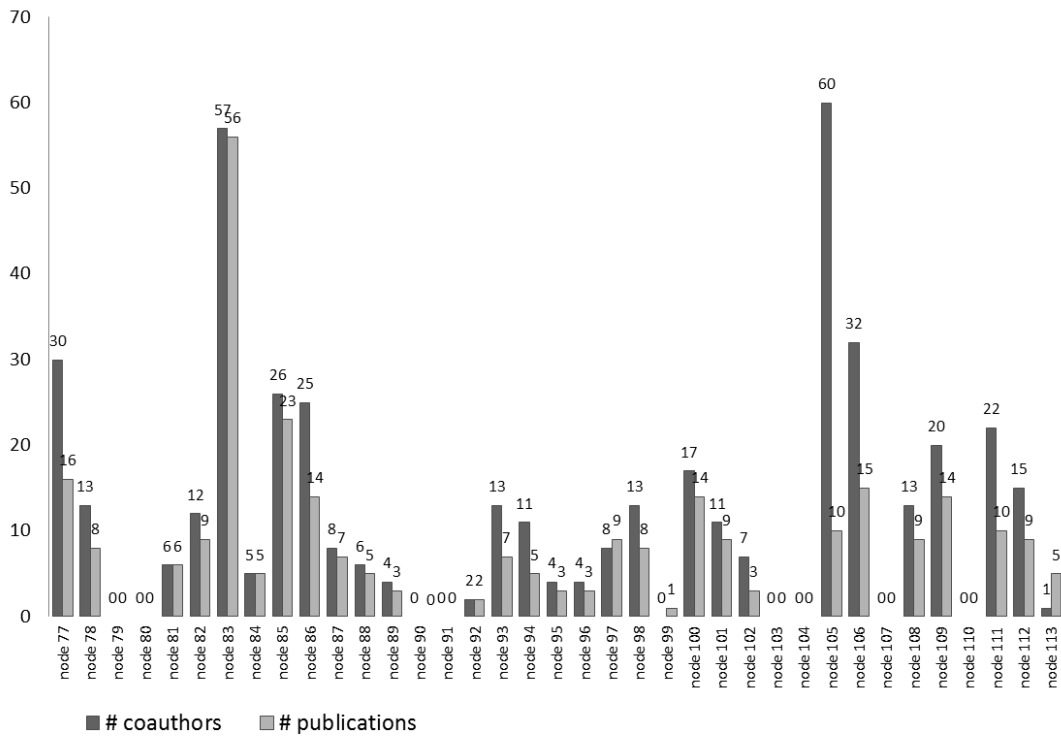


Figure 7. Department of Strategy and Management: number of coauthors vs. number of publications

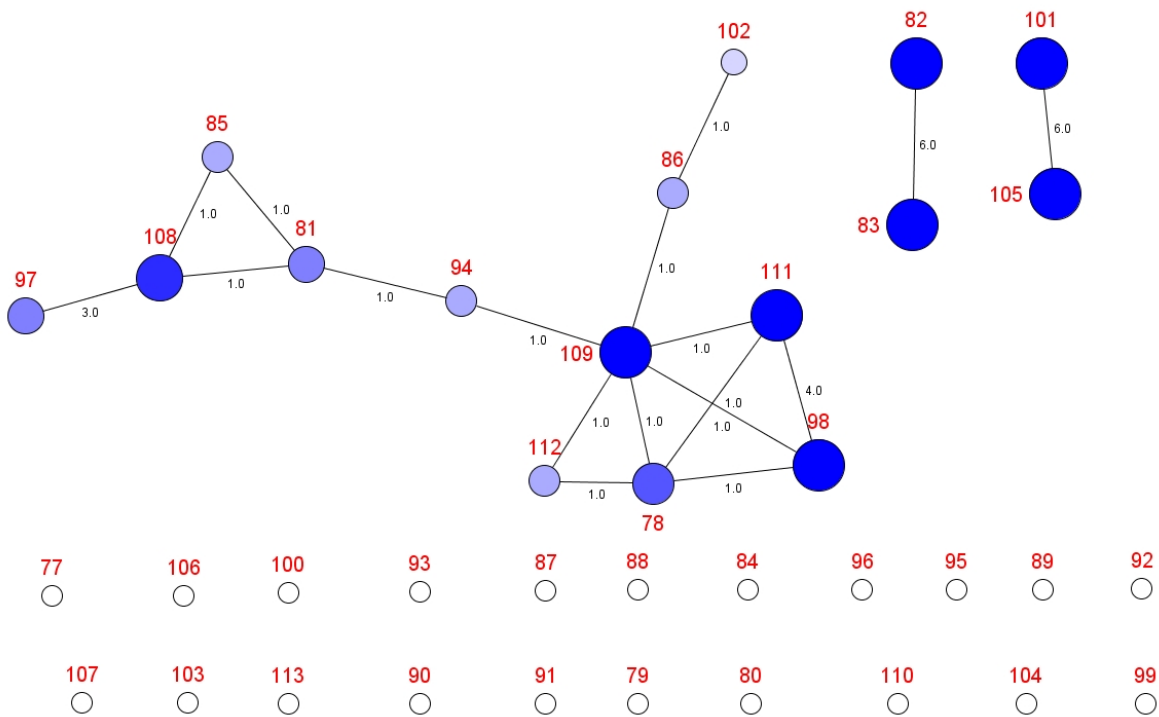


Figure 8. Department of Strategy and Management – the internal coauthorship network

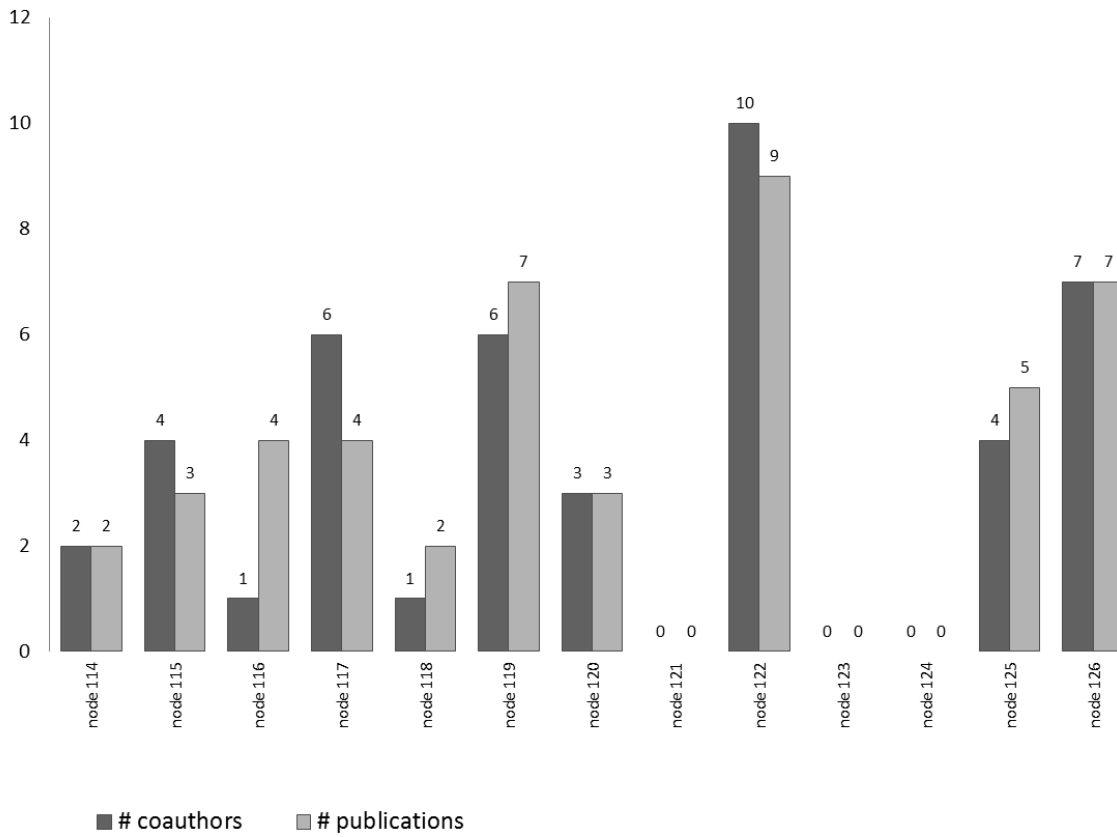


Figure 10. Department of Finance:
number of coauthors vs. number of publications

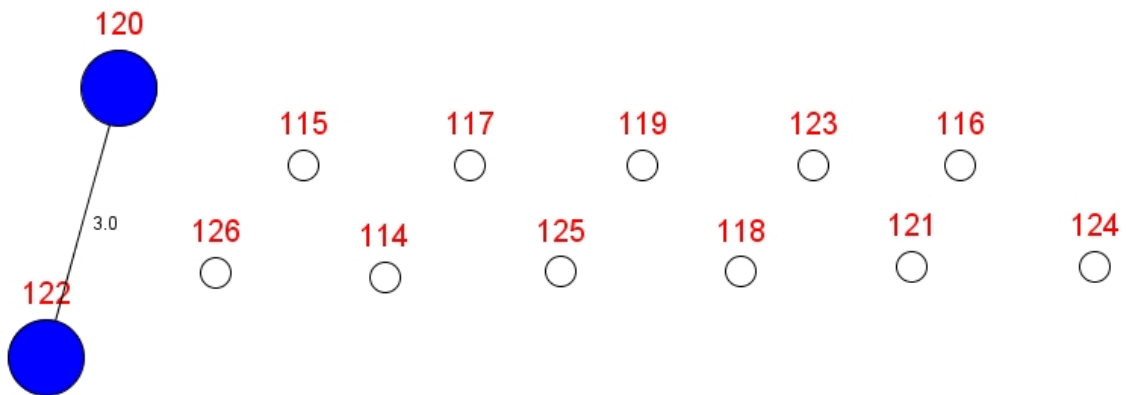


Figure 11. Department of Finance – the internal coauthorship network

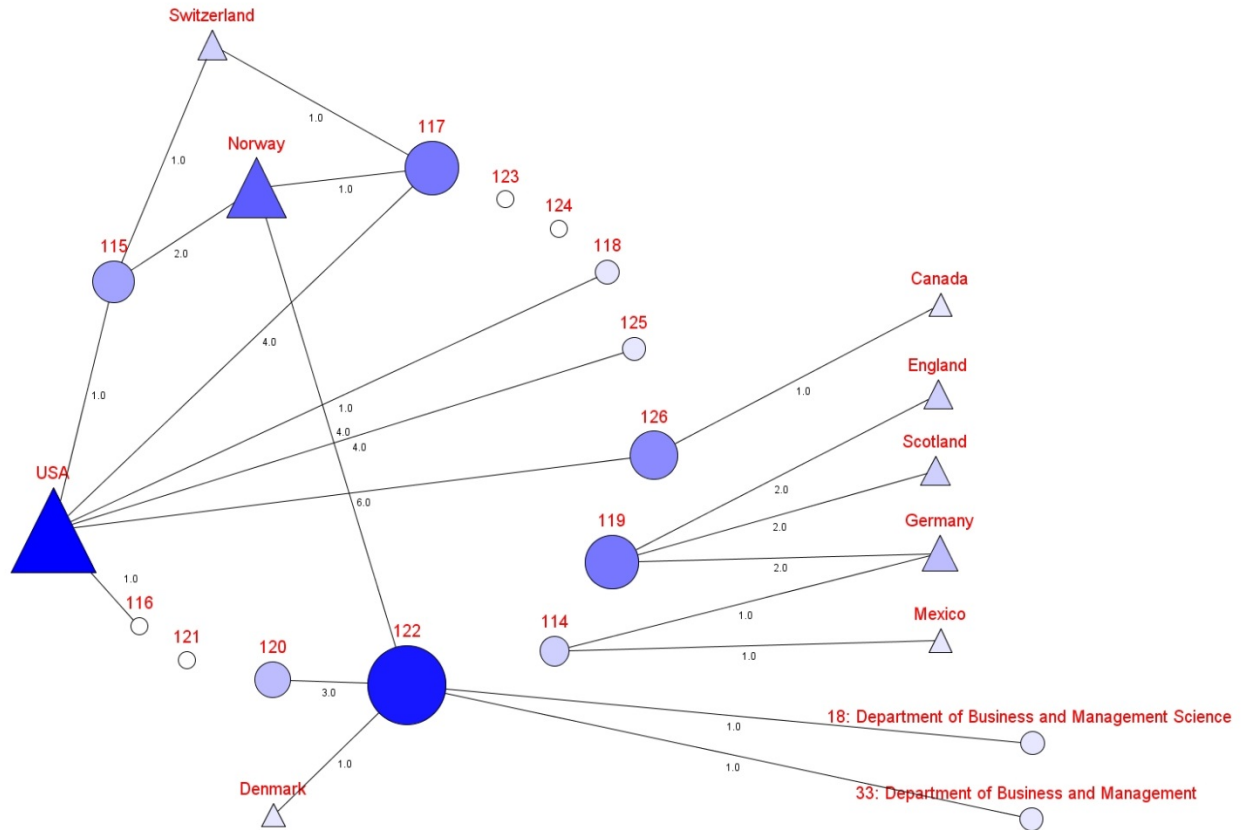


Figure 12. Department of Finance – the overall coauthorship network

2.5 Department of Accounting, Auditing and Law

Table 5. Coauthorship and the number of publications by persons

Faculty	Coauthorship				Number of publications
	internal	Interdep.	external	total	
node 127	0	0	0	0	0
node 128	0	0	0	0	0
node 129	1	0	6	7	4
node 130	0	3	7	10	8
node 131	0	0	0	0	4
node 132	0	0	8	8	5
node 133	0	0	0	0	0
node 134	1	0	0	1	1
node 135	0	0	0	0	0
node 136	0	0	0	0	0
node 137	1	2	0	3	2
node 138	1	1	8	10	7
node 139	0	0	0	0	0
node 140	0	0	2	2	3
node 141	0	0	0	0	0
node 142	0	2	3	5	7
node 143	0	0	2	2	1

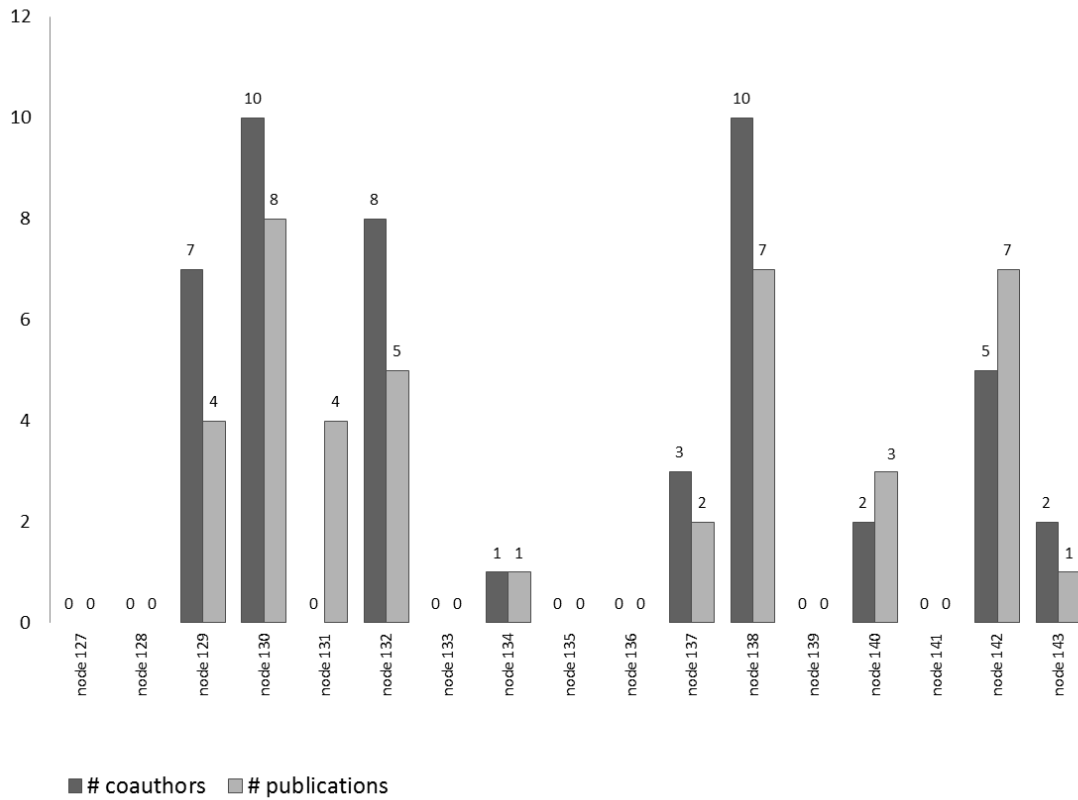


Figure 13. Department of Accounting, Auditing and Law: number of coauthors vs. number of publications

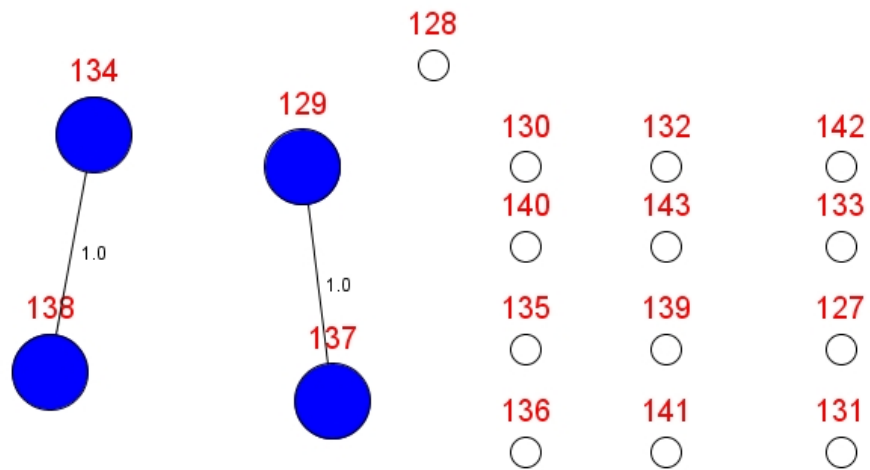


Figure 14. Department of Accounting, Auditing and Law – the internal coauthorship network

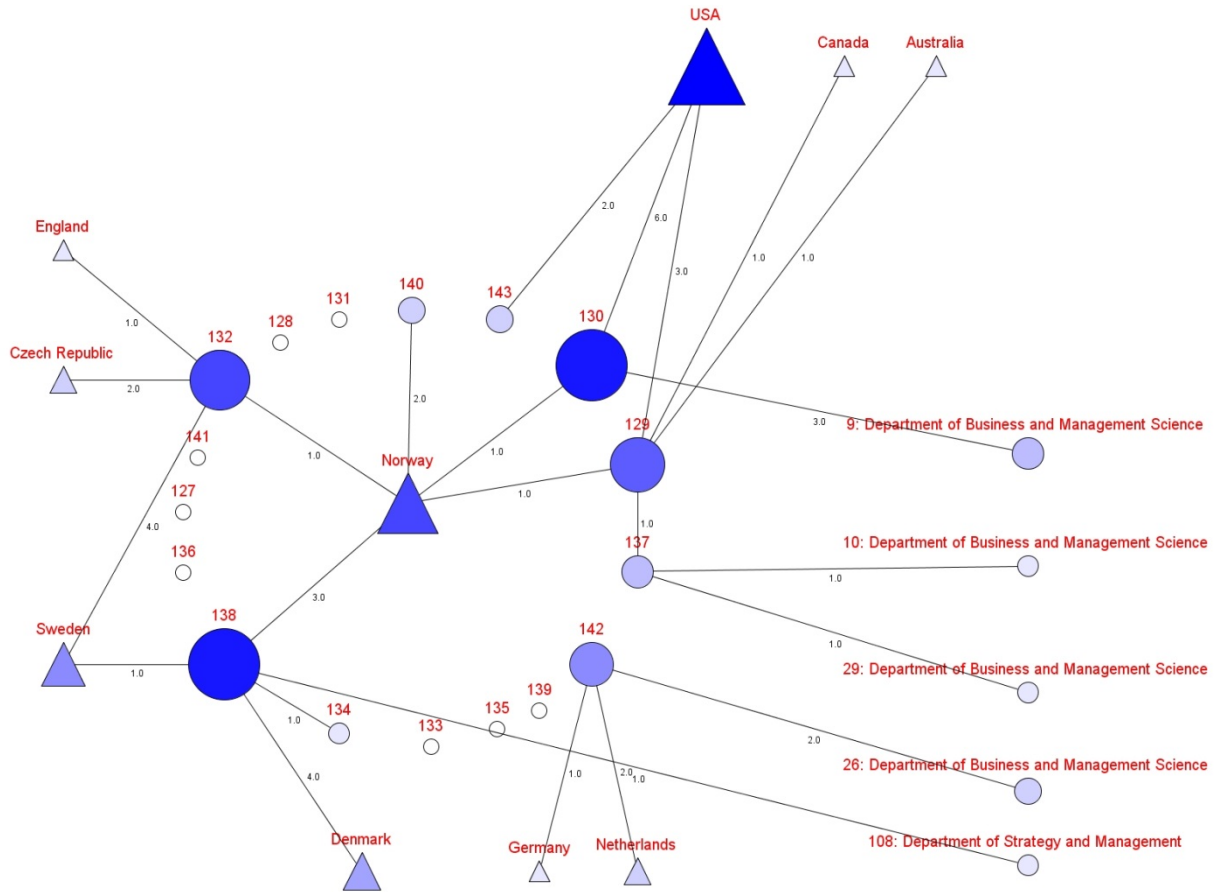


Figure 15. Department of Accounting, Auditing and Law – the overall coauthorship network

2.6 Department of Professional and Intercultural Communication

Table 6. Coauthorship and the number of publications by persons

Faculty	Coauthorship				Number of publications
	internal	Interdep.	external	total	
node 144	0	0	0	0	0
node 145	0	0	0	0	2
node 146	0	0	1	1	4
node 147	0	0	1	1	2
node 148	0	0	0	0	1
node 149	0	0	0	0	0
node 150	0	0	0	0	3
node 151	0	0	0	0	0
node 152	0	0	0	0	0
node 153	0	0	0	0	0
node 154	0	0	0	0	0
node 155	0	0	0	0	0
node 156	0	0	0	0	0

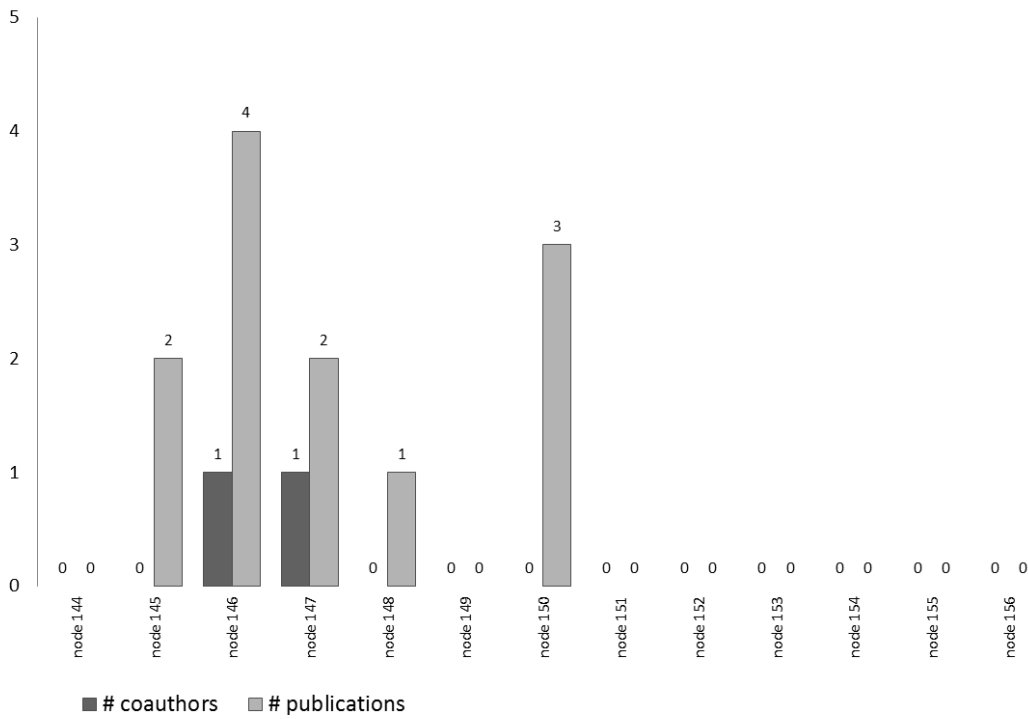


Figure 16. Department of Professional and Intercultural Communication: number of coauthors vs. number of publications

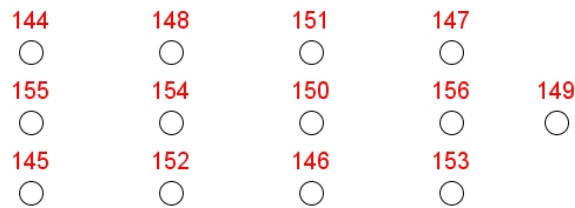


Figure 17. Department of Professional and Intercultural Communication – the internal coauthorship network

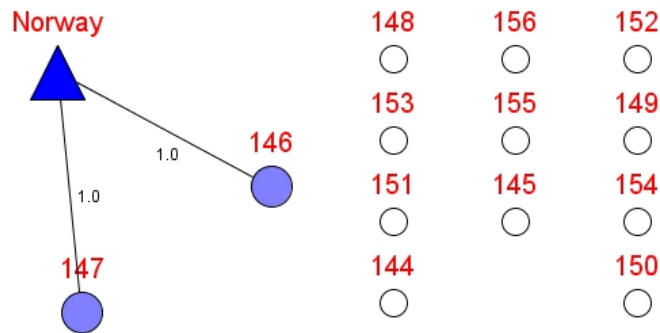


Figure 18. Department of Professional and Intercultural Communication – the overall coauthorship network

2.6 The interdepartmental coauthorship network

There are 24 NHH faculty member that are involved in the 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 7).

Table 7. 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								

The detailed representation of the interdepartmental coauthorship is represented in Figure 19.

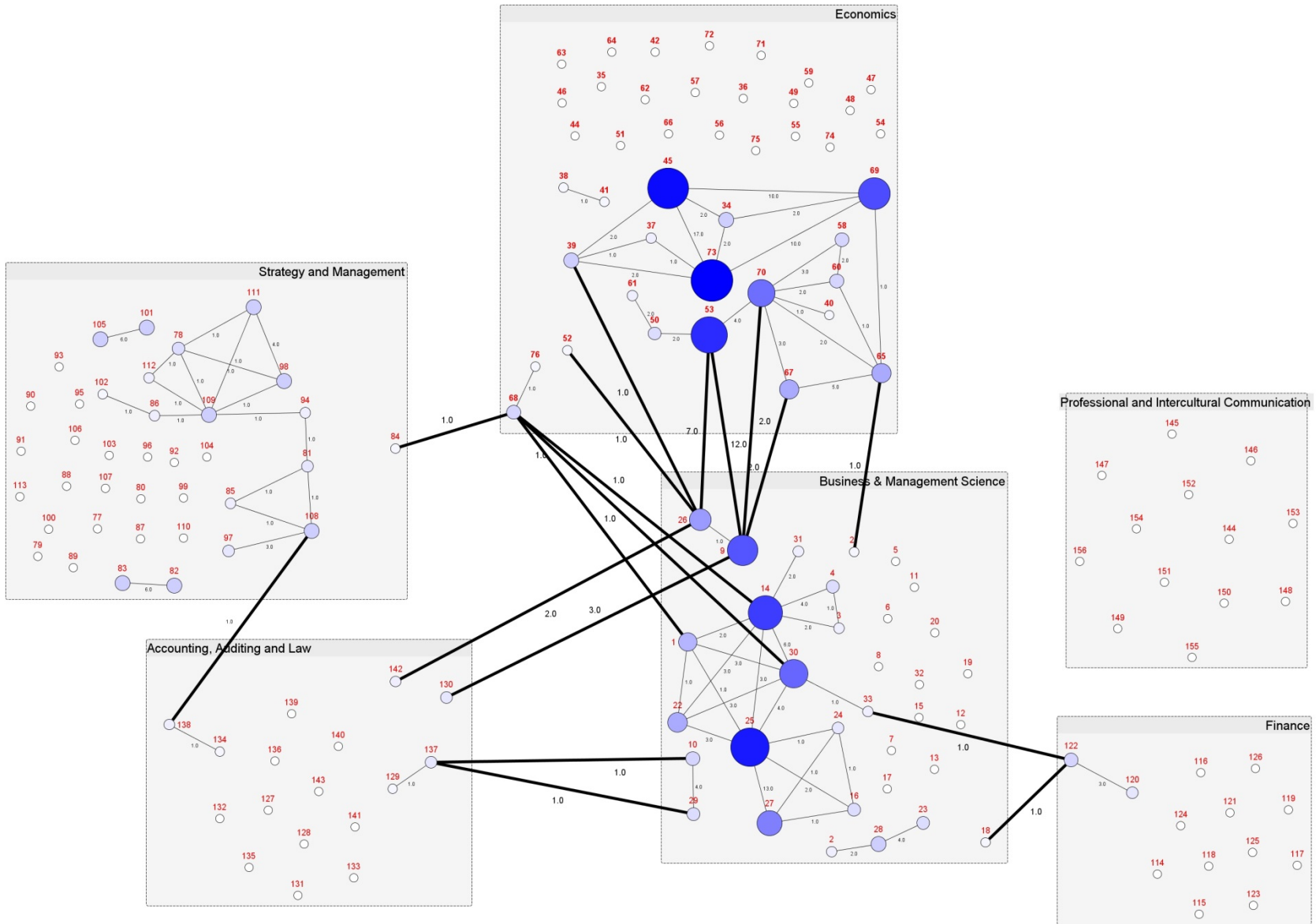


Figure 19. The interdepartmental coauthorship network

3. CLIQUES' ANALYSIS

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 the joint scientific paper(s) with all other clique members.

In terms of this paper, we are looking for the maximum cliques and 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. Maximum clique is the largest group of faculty members that are collaborating in terms of publishing joint papers.

Although we are looking for cliques with $k \geq 3$, we also report the two-vertex cliques if they form the maximum cliques within the departments. Finding the maximum clique is an NP-complete problem, and there are no algorithms solving the problem in polynomial time (Östergård, 2002). However, finding the maximum clique in comparatively small graphs, such as the NHH coauthorship network, is a feasible task.

3.1 Department of Business and Management Science

The maximum clique consists of five faculty member:

1. node 1;
2. node 14;
3. node 22;
4. node 25;
5. node 30.

The given maximum ($k=5$) clique is represented in Figure 20.

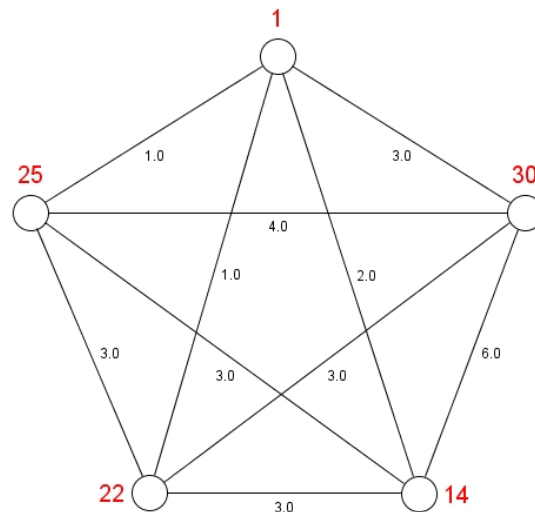


Figure 20. Maximum (five-vertex) clique in the Department of Business and Management Science

The second largest clique ($k=4$) contains four faculty members (see Figure 21):

1. node 16;
2. node 24;
3. node 25;
4. node 27.

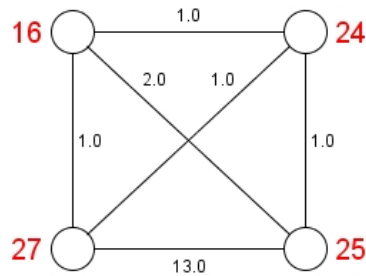


Figure 21. Four-vertex clique in the Department of Business and Management Science

The core cliques-based structure of the Department consists of three cliques interconnected by two hubs: node 25 and node 14. It is illustrated in Figure 22.

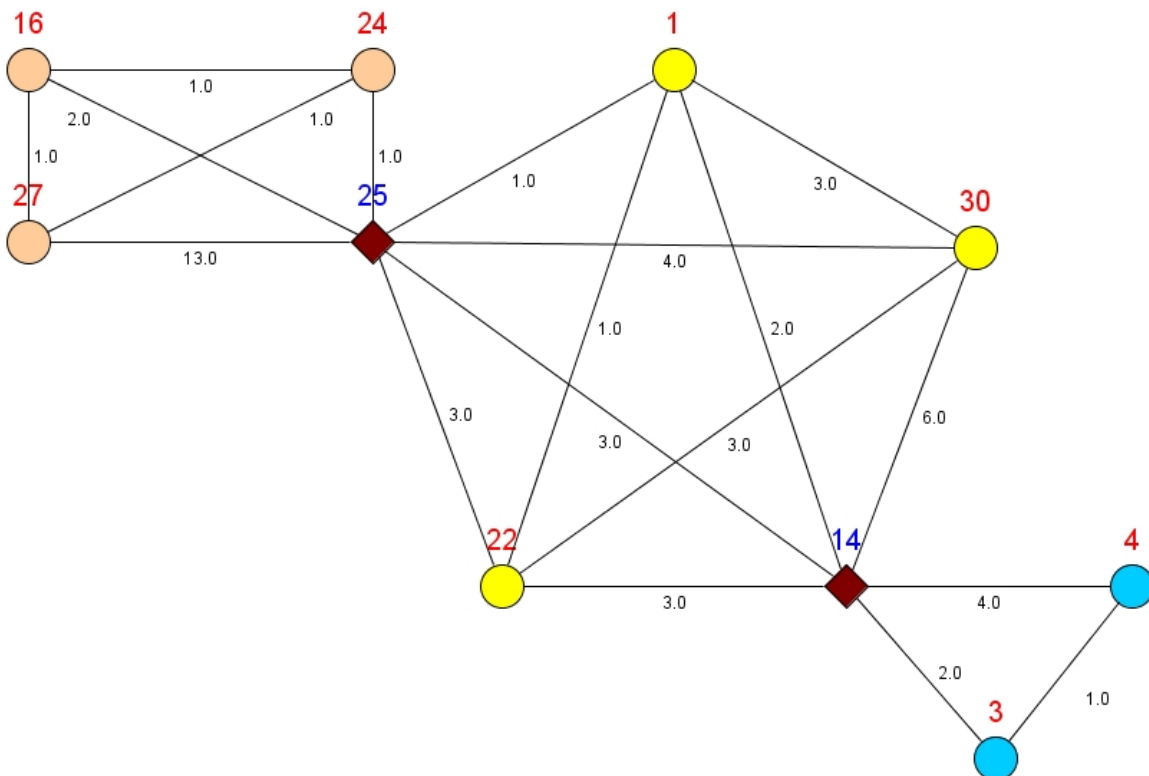


Figure 22. Core cliques-based structure of the Department of Business and Management Science

3.2 Department of Economics

The maximum clique in the Department of Economics consists of four faculty members (see Figure 23):

1. node 34;
2. node 45;
3. node 69;
4. node 73.

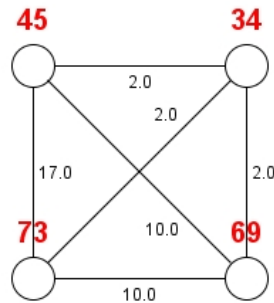


Figure 23. Maximum (four-vertex) clique in the Department of Economics

There are five cliques of size $k=3$ that are not the sub-graphs of the maximum four-vertex clique. These five three-vertex cliques are represented separately in Figure 24:

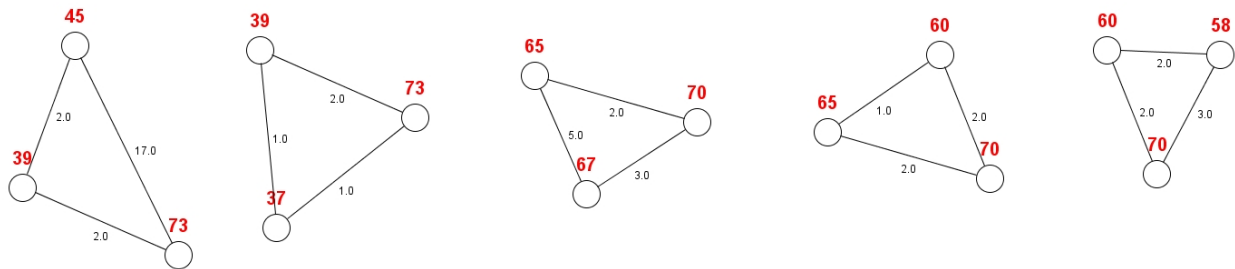


Figure 24. Three-vertex cliques in the Department of Economics

The cliques' interconnection is represented in Figure 25. According to the given representation it is clear to see 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 two largest cliques-based sub-graphs (i.e., Component 1 and Component 2).

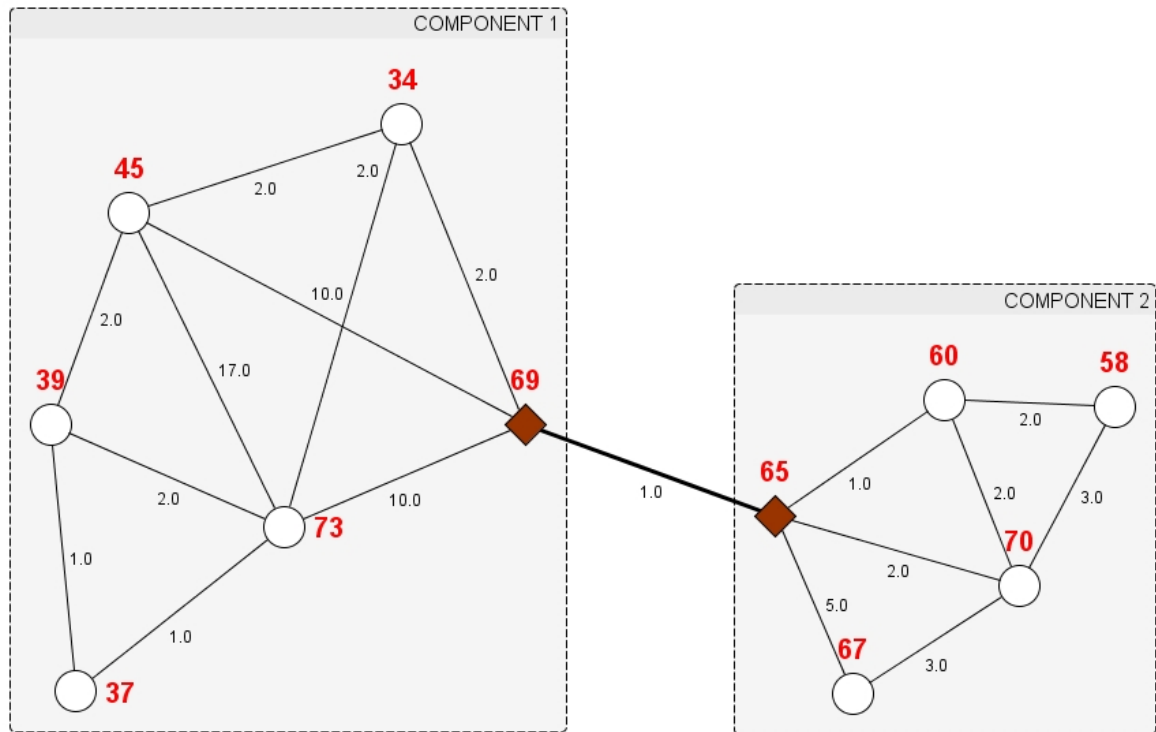


Figure 25. Core cliques-based structure of the Department of Economics

3.3 Department of Strategy and Management

The maximum clique consists of four faculty members (see Figure 26):

1. node 78;
2. node 98;
3. node 109;
4. node 111.

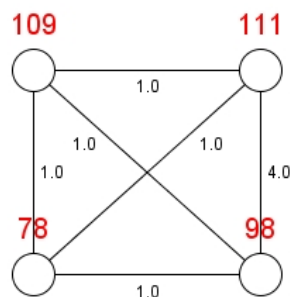


Figure 26. Maximum (four-vertex) clique in the Department of Strategy and Management

Since one person (i.e., node 112) is affiliated with the maximum clique by the existing links to node 109 and node 78, we have a three-vertex clique represented in Figure 27.

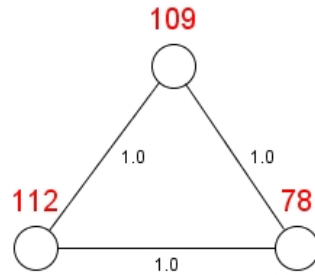


Figure 27. First three-vertex clique in the Department of Strategy and Management

Another three-vertex clique, which is not connected to the cliques mentioned above, consists of the following faculty members (see Figure 28):

1. node 81;
2. node 85;
3. node 108.

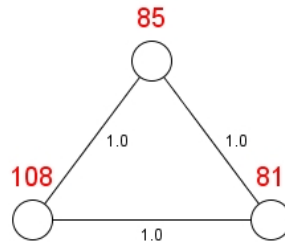


Figure 28. Second three-vertex clique in the Department of Strategy and Management

The core clique-based structure of the Department of Strategy and Management consists of three cliques. The first three-vertex clique (see Figure 27) is interconnected with the maximum clique (see Figure 26) by the participation of two faculty members (i.e., node 109 and node 78) in both cliques. It forms the Component 1. The second three-vertex clique (see figure 28) forms the 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 is represented in Figure 29.

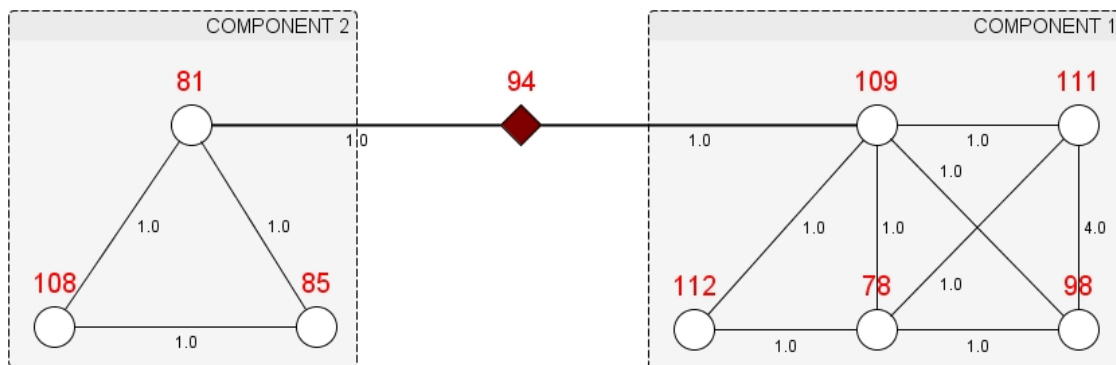


Figure 29. Core cliques-based structure of the Department of Strategy and Management

3.4. Department of Finance

The maximum clique in the Department of Finance is a two-vertex clique. It consists of the following faculty members: “node 120” and “node 122” (see Figure 30):

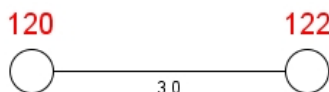


Figure 30. Maximum (two-vertex) clique in the Department of Finance

3.5 Department of Accounting, Auditing and Law

There are two maximum cliques, both consisting of two vertices (see Figure 31). The first clique: “node 134” and “node 138”. The second clique: “node 129” and “node 137”. No other cliques exist in the Department of Accounting, Auditing and Law.

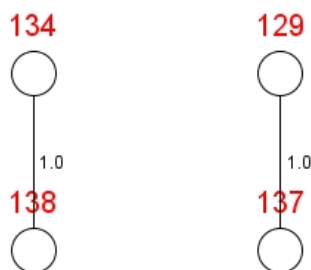


Figure 31. Two maximum (two-vertex) cliques in the Department of Accounting, Auditing and Law

3.6 Department of Professional and Intercultural Communication

There are no cliques in the Department of Professional and Intercultural Communication

3.7 Trans-departmental cliques

The trans-departmental clique is the clique where $k \geq 3$ and at least two clique members are the members of different departments. In this case, we are not interested in two-vertex trans-departmental cliques, because they simply correspond to the single interdepartmental links. This type of links is reported in Section 2.6.

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.

All of the maximum trans-departmental cliques have the size of $k=3$.

There are seven three-vertex cliques that are split into three graphs (see Figure 32).

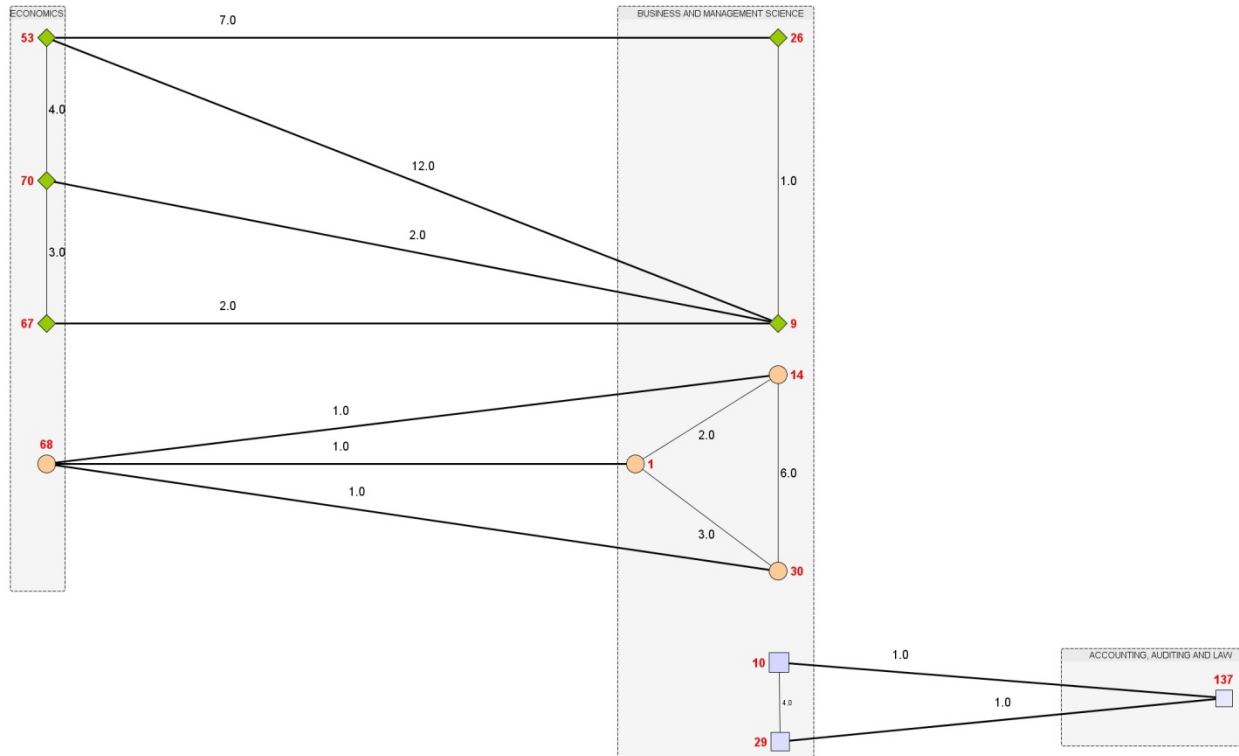


Figure 32. Trans-departmental cliques

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:

1. “node 10” – “node 29” – “node 137”.

4. SPANNING TREES AND SPANNING FORESTS

We analyze the departmental and interdepartmental coauthorship networks in order to detect the 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 coauthorship network is represented by the set of disconnected graphs, we are looking for the set of spanning trees of the disconnected components, which is called a spanning forest (Bollobás, 1998).

Analyzing cliques in Section 3 we detected the groups of the most strongly connected faculty members in terms of the coauthorship, but detecting the spanning trees we are looking for the overall affiliation of the faculty members with the NHH research community. 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 coauthorship network. We analyze the spanning forests for each department separately and then we build the spanning forest for the interdepartmental relations.

4.1 Department of Business and Management Science

The departmental spanning forest consists of four spanning trees represented in Figure 33.

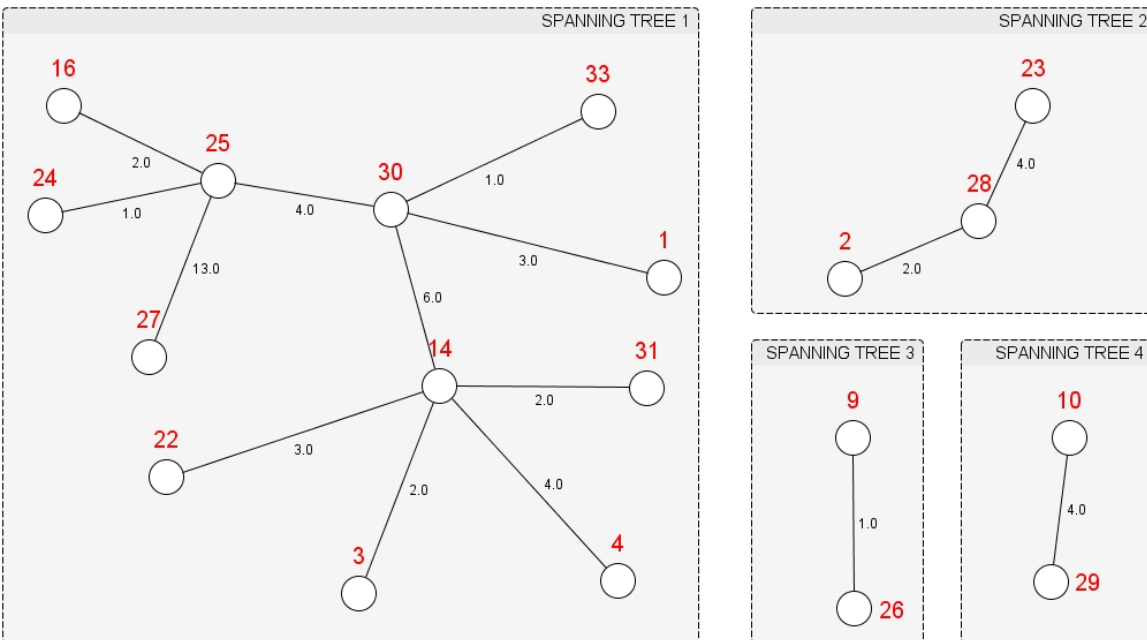


Figure 33. Spanning forest of the Department of Business and Management Science

According to Figure 33 spanning tree 1 is the maximal. It consists of twelve faculty members:

- | | |
|-------------|--------------|
| 1. node 1; | 7. node 24; |
| 2. node 3; | 8. node 25; |
| 3. node 4; | 9. node 27; |
| 4. node 14; | 10. node 30; |
| 5. node 16; | 11. node 31; |
| 6. node 22; | 12. node 33. |

In spanning tree 1 we specify three hubs: “node 25”, “node 14”, and “node 30”.

Spanning tree 2 consists of three faculty members: node 2, node 23, and node 28. In this tree “node 28” is detected as the hub.

Each of two other spanning trees (i.e., spanning tree 3 and spanning tree 4) consists of two faculty members: node 9 – node 26 and node 10 – node 29, respectively.

4.2 Department of Economics

The spanning forest of the Department of Economics contains three spanning trees (see Figure 34).

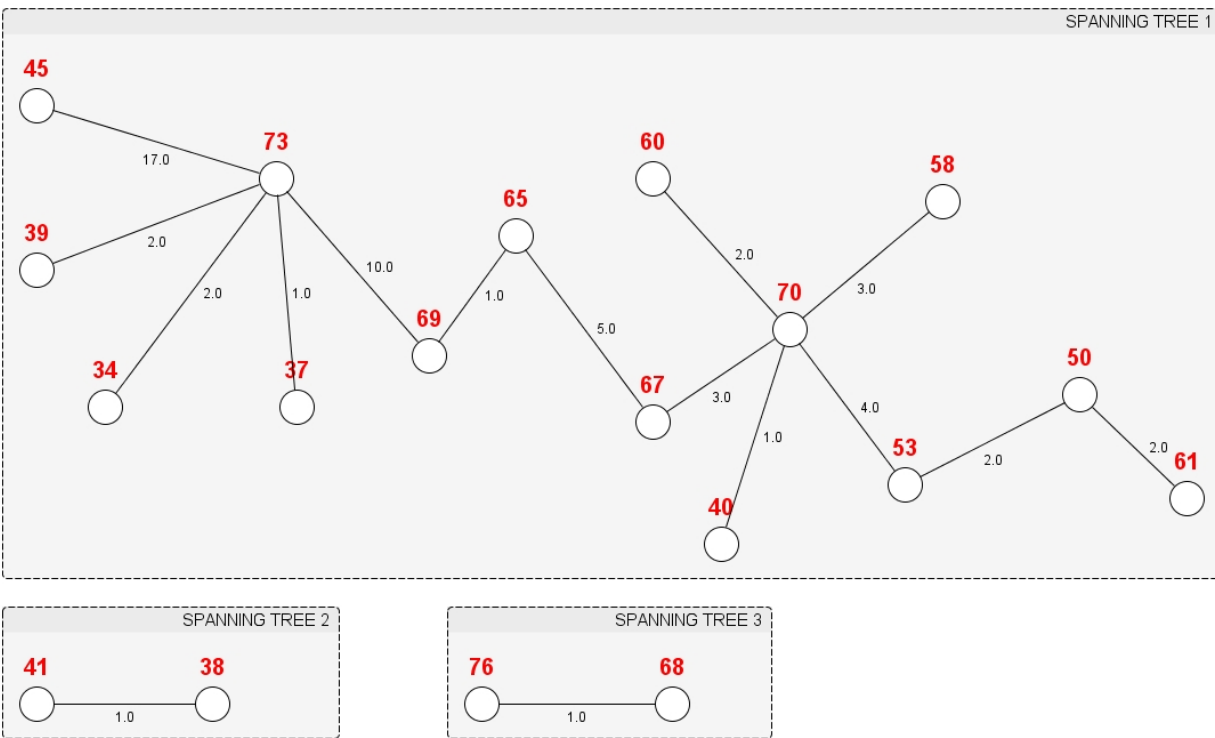


Figure 34. Spanning forest of the Department of Economics

Spanning tree 1 is the maximal. It consists of 15 faculty members:

- | | |
|-------------|--------------|
| 1. node 34; | 9. node 60; |
| 2. node 37; | 10. node 61; |
| 3. node 39; | 11. node 65; |
| 4. node 40; | 12. node 67; |
| 5. node 45; | 13. node 69; |
| 6. node 50; | 14. node 70; |
| 7. node 53; | 15. node 73. |
| 8. node 58; | |

Two other spanning trees are two-vertex graphs formed by the following faculty members: “node 41” – “node 38” in spanning tree 2, and “node 76” – “node 68” in spanning tree 3.

4.3 Department of Strategy and Management

The departmental spanning forest consists of three spanning trees (see Figure 35).

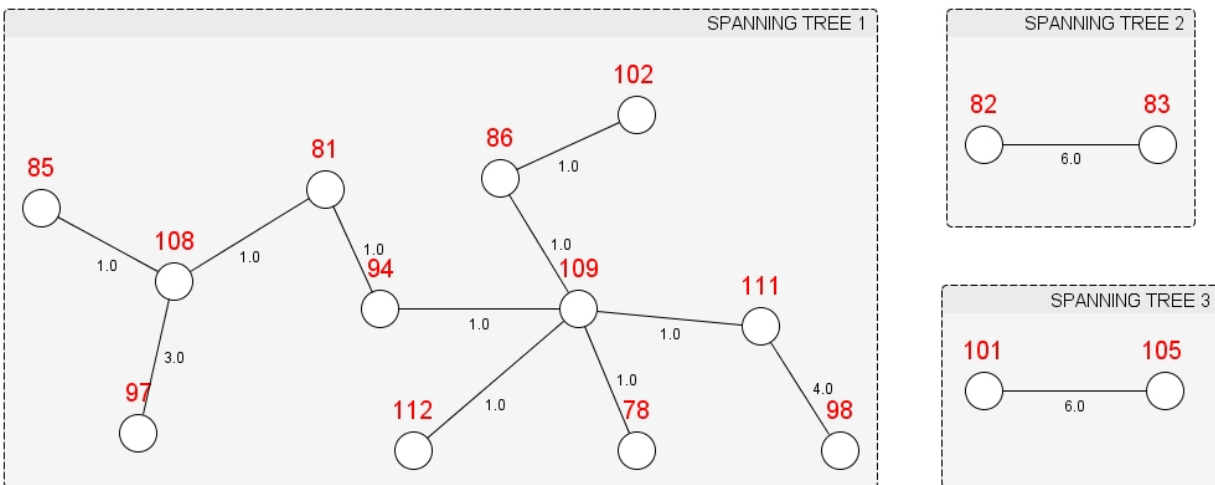


Figure 35. Spanning forest of the Department of Strategy and Management

Spanning tree 1 is the maximal and consists of 12 faculty members:

- | | |
|-------------|---------------|
| 1. node 78; | 7. node 98; |
| 2. node 81; | 8. node 102; |
| 3. node 85; | 9. node 108; |
| 4. node 86; | 10. node 109; |
| 5. node 94; | 11. node 111; |
| 6. node 97; | 12. node 112. |

According to Figure 35, the most central hub of the tree is “node 109”.

Spanning tree 2 and spanning tree 3 consist of two-vertex graphs: “node 82” – “node 83” and “node 101” – “node 105”, respectively.

4.4. Department of Finance

The departmental spanning tree is represented by the only two-vertex graph: “node 120” – “node 122” (see Figure 36).

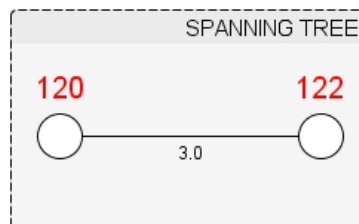


Figure 36. Spanning tree of the Department of Finance

4.5 Department of Accounting, Auditing and Law

The departmental spanning forest is represented by two spanning trees: “node 134” – “node 138” is the spanning tree 1, and “node 129” – “node 137” is the spanning tree 2 (see Figure 37).

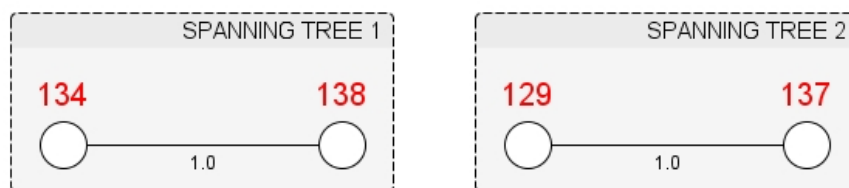


Figure 37. Spanning forest of the Department of Accounting, Auditing and Law

4.6 Department of Professional and Intercultural Communication

The departmental spanning forest is not detected.

4.7 Trans-departmental spanning forest

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.

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 structure is represented in Figure 38.

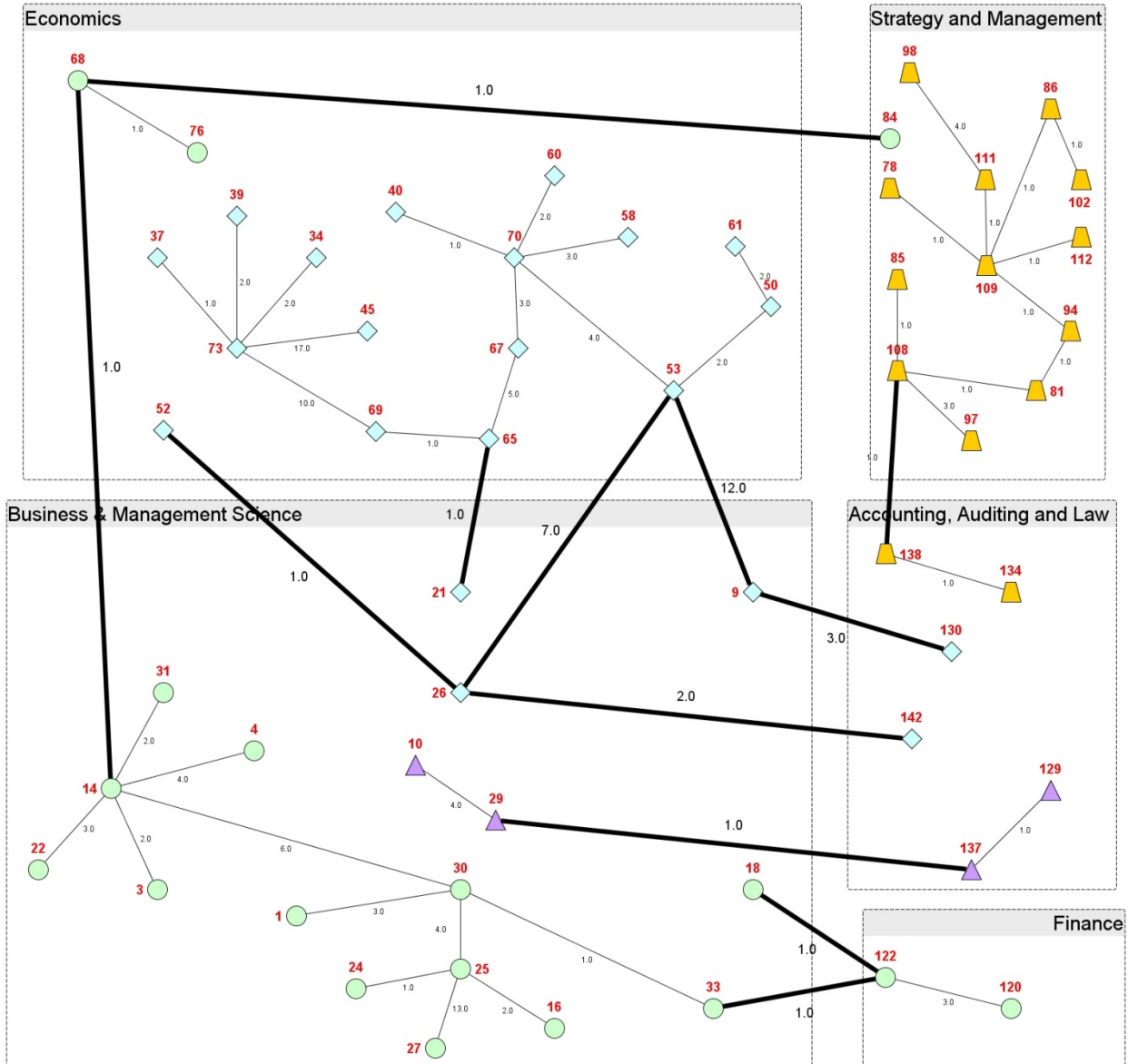


Figure 38. Trans-departmental spanning forest

According to Figure 38 the spanning forest consists of four spanning trees.

The maximal spanning tree (see Figure 39) covers three departments and includes 21 faculty members listed in Table 8.

Table 8. Maximal spanning tree in the 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				

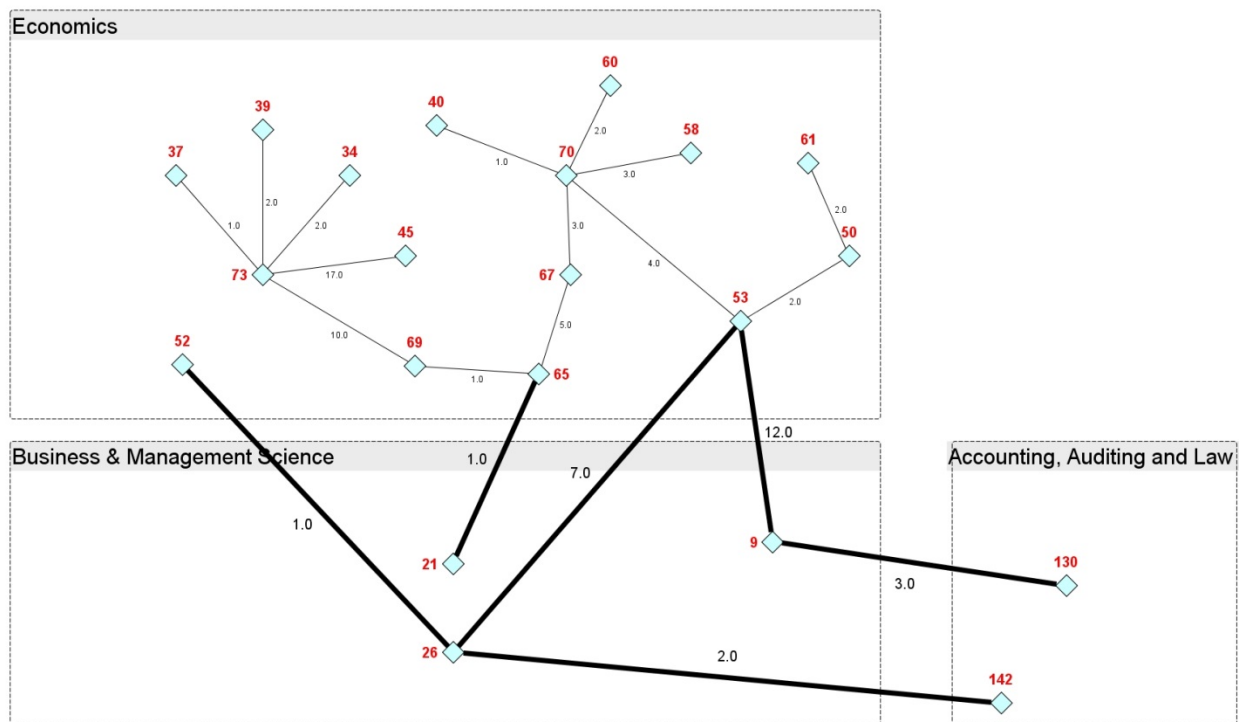


Figure 39. Maximal spanning tree in the trans-departmental forest

The second largest spanning tree consists of 18 faculty member from four departments (see Table 40):

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

Figure 40. The second largest spanning tree in the 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 40 is represented in Figure 41.

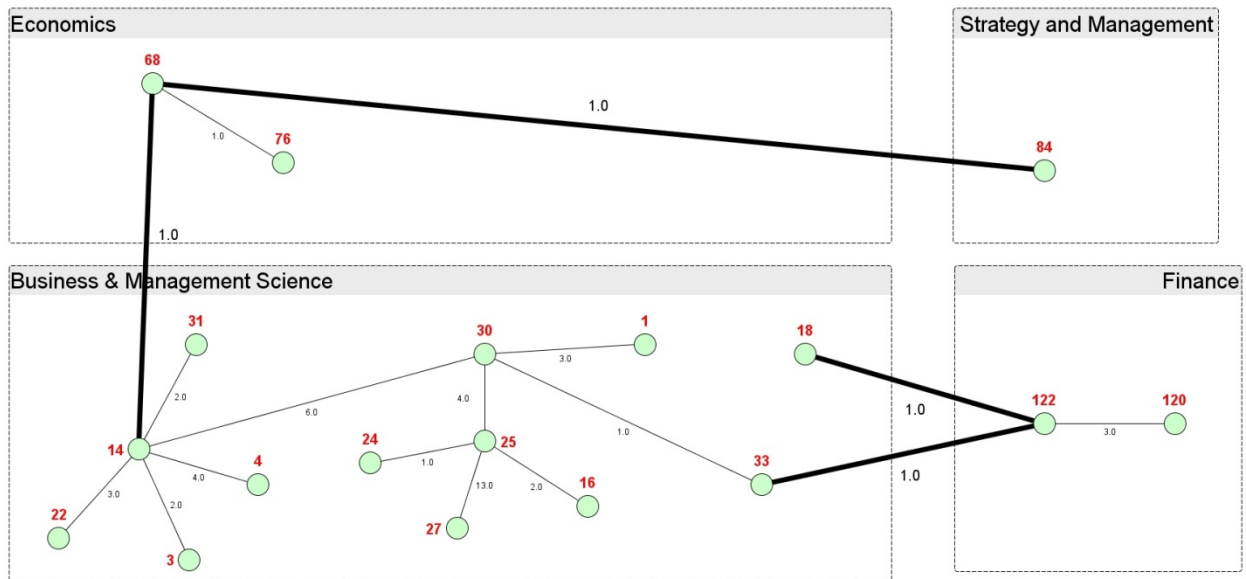


Figure 41. Second largest spanning tree in the trans-departmental forest

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 41). The given spanning tree is formed based on 14 faculty members represented in Table 9.

Table 9. 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		

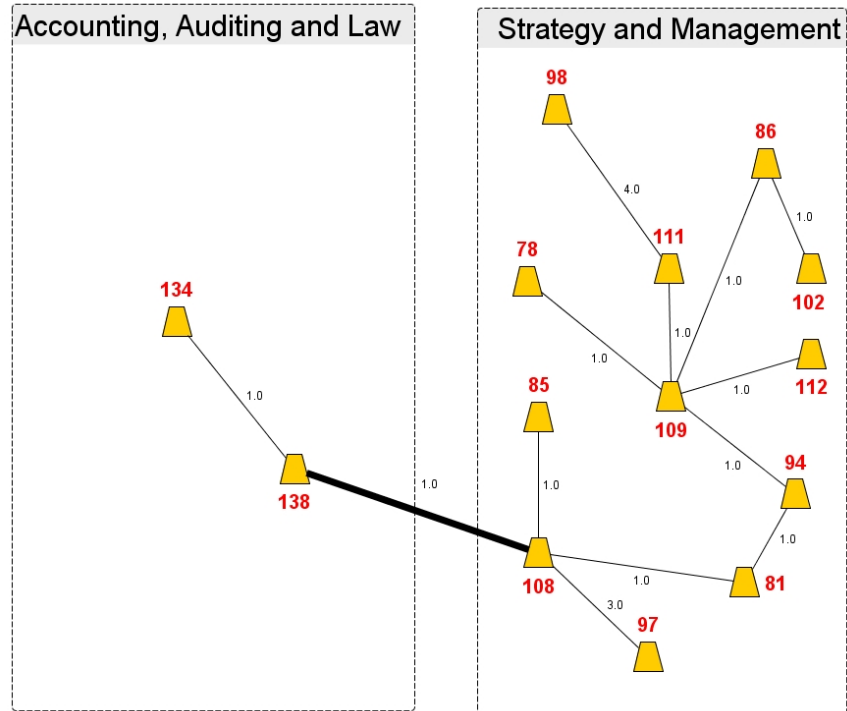


Figure 42. The third largest spanning tree in the trans-departmental forest

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 43.

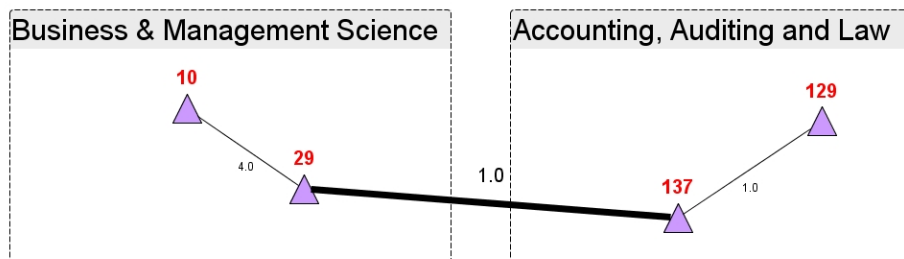


Figure 43. The smallest spanning tree in the trans-departmental forest

5. INTERNATIONAL COAUTHORSHIP

In this section we analyse the existing international coauthorship (based on *the ISI Web of Science*) that cover all countries excepting Norway. We investigate how many faculty members at the NHH coauthorship network should be deleted in order for the international coauthorship to be vanishing. To approach this goal we sort the faculty members by the number of international coauthorship (i.e., by the number of coauthors from non-Norwegian institutions) in the descending order. Then, we delete them from the list one by one until we get the international coauthorship vanished. This procedure is done for the NHH departments in sections 5.1 – 5.5 and for the overall NHH coauthorship in section 5.6.

We represent the results in tabular format (see Tables 10-15) where we provide the following information:

- “number of coauthorship” is the number of international coauthors for the corresponding faculty member;
- “overall after exclusion” is the number of the overall international coauthorship left after excluding the current author and authors excluded earlier in the sorted list.
- “% out of overall coauthorship” is the percentage of the faculty member’s contribution out of the overall NHH international coauthorship.
- “Overall % after exclusion” is the overall percentage of international coauthorship after excluding the current author and authors excluded earlier in the sorted list.

The graphical representation is given in Figures 44-49.

5.1 Department of Business and Management Science

There are 266 international coauthorships in the Department. The sorted list of faculty members is represented in Table 10. The deletion of 23 out of 33 (approximately, 70% out of 100%) faculty members will lead to the vanishing of the international coauthorship. It is important to notice that the deletion of only 4 out of 33 faculty members (i.e., approx. 12% out of 100%) will bring more than 50% reduction of the departmental international coauthorship.

The given results are represented in Figure 44.

Table 10. Department of Business and Management Science:
International coauthorship by faculty members

	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 14	54	212	20.3	79.7		18	node 21	2	6	0.8	2.3
2	node 31	32	180	12.0	67.7		19	node 22	2	4	0.8	1.5
3	node 27	27	153	10.2	57.5		20	node 1	1	3	0.4	1.1
4	node 11	21	132	7.9	49.6		21	node 7	1	2	0.4	0.8
5	node 26	21	111	7.9	41.7		22	node 19	1	1	0.4	0.4
6	node 8	18	93	6.8	35.0		23	node 33	1	0	0.4	0.0
7	node 16	14	79	5.3	29.7		24	node 2	0	0	0.0	0.0
8	node 4	11	68	4.1	25.6		25	node 5	0	0	0.0	0.0
9	node 15	11	57	4.1	21.4		26	node 10	0	0	0.0	0.0
10	node 25	11	46	4.1	17.3		27	node 12	0	0	0.0	0.0
11	node 30	11	35	4.1	13.2		28	node 18	0	0	0.0	0.0
12	node 3	8	27	3.0	10.2		29	node 20	0	0	0.0	0.0
13	node 9	6	21	2.3	7.9		30	node 24	0	0	0.0	0.0
14	node 23	5	16	1.9	6.0		31	node 28	0	0	0.0	0.0
15	node 17	4	12	1.5	4.5		32	node 29	0	0	0.0	0.0
16	node 6	2	10	0.8	3.8		33	node 32	0	0	0.0	0.0
17	node 13	2	8	0.8	3.0							

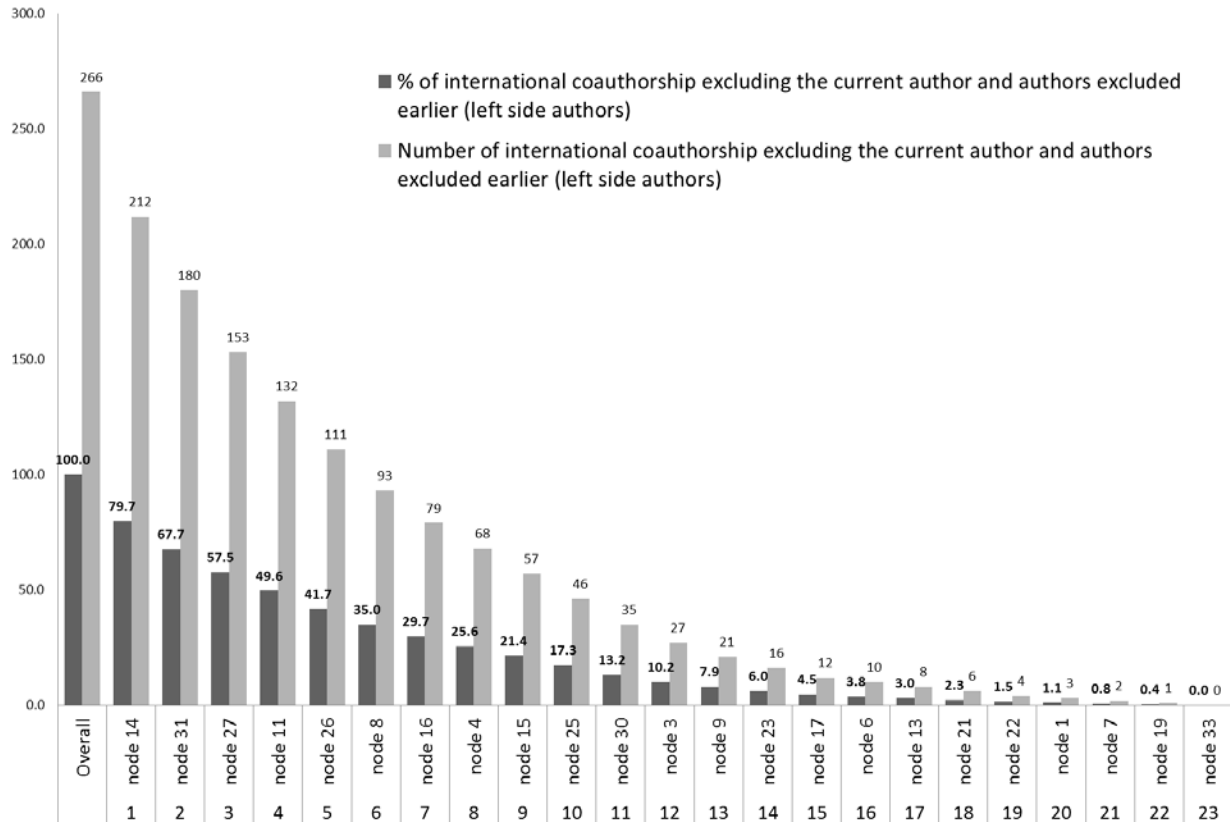


Figure 44. Department of Business and Management Science:
International coauthorship based on the sequential faculty members' deletion

5.2 Department of Economics

There are 262 international coauthorships in the Department. The sorted list of faculty members is represented in Table 11. The deletion of 33 out of 43 (approximately, 77% out of 100%) faculty members will lead to the vanishing of the international coauthorship. It is important to notice that the deletion of only 4 out of 43 faculty members (i.e., approx. 9% out of 100%) will bring more than 50% reduction of the departmental international coauthorship. The given results are represented in Figure 45.

Table 11. Department of Economics:
International coauthorship by faculty members

	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	207	21.0	79.0		23	node 44	2	15	0.8	5.7
2	node 65	41	166	15.6	63.4		24	node 45	2	13	0.8	5.0
3	node 40	25	141	9.5	53.8		25	node 57	2	11	0.8	4.2
4	node 73	20	121	7.6	46.2		26	node 58	2	9	0.8	3.4
5	node 53	11	110	4.2	42.0		27	node 60	2	7	0.8	2.7
6	node 55	10	100	3.8	38.2		28	node 70	2	5	0.8	1.9
7	node 39	9	91	3.4	34.7		29	node 37	1	4	0.4	1.5
8	node 61	9	82	3.4	31.3		30	node 59	1	3	0.4	1.1
9	node 50	8	74	3.1	28.2		31	node 67	1	2	0.4	0.8
10	node 62	8	66	3.1	25.2		32	node 71	1	1	0.4	0.4
11	node 46	7	59	2.7	22.5		33	node 72	1	0	0.4	0.0
12	node 66	6	53	2.3	20.2		34	node 41	0	0	0.0	0.0
13	node 51	5	48	1.9	18.3		35	node 43	0	0	0.0	0.0
14	node 68	5	43	1.9	16.4		36	node 47	0	0	0.0	0.0
15	node 42	4	39	1.5	14.9		37	node 48	0	0	0.0	0.0
16	node 56	4	35	1.5	13.4		38	node 49	0	0	0.0	0.0
17	node 69	4	31	1.5	11.8		39	node 52	0	0	0.0	0.0
18	node 34	3	28	1.1	10.7		40	node 63	0	0	0.0	0.0
19	node 36	3	25	1.1	9.5		41	node 64	0	0	0.0	0.0
20	node 54	3	22	1.1	8.4		42	node 74	0	0	0.0	0.0
21	node 76	3	19	1.1	7.3		43	node 75	0	0	0.0	0.0
22	node 35	2	17	0.8	6.5							

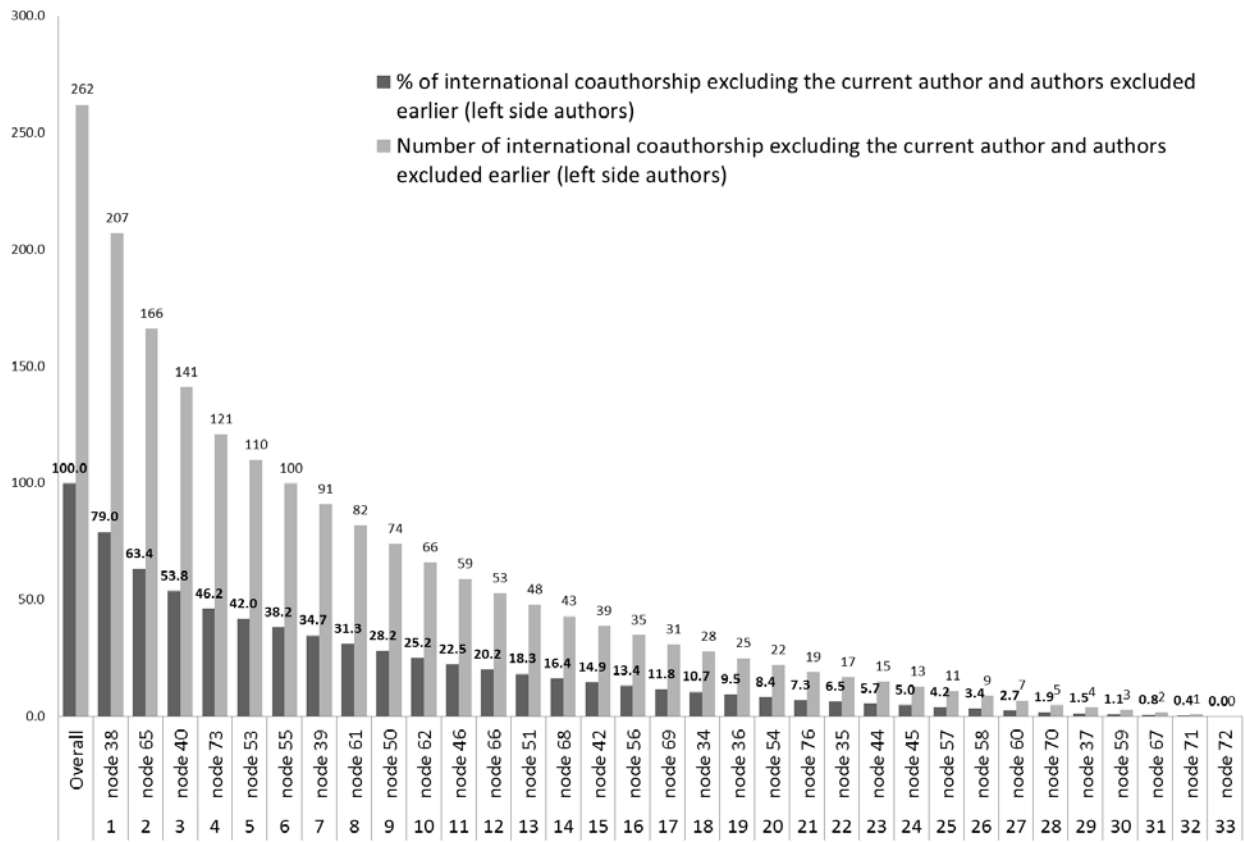


Figure 45. Department of Economics:
International coauthorship based on the sequential faculty members' deletion

5.3 Department of Strategy and Management

There are 208 international coauthorships in the Department. The sorted list of faculty members is represented in Table 12. The deletion of 21 out of 37 (approximately, 57% out of 100%) faculty members will lead to the vanishing of the international coauthorship. It is important to notice that the deletion of only 3 out of 37 faculty members (i.e., approx. 8% out of 100%) will bring almost 58% reduction of the departmental international coauthorship. The given results are represented in Figure 46.

Table 12. Department of Strategy and Management: International coauthorship by faculty members

	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 83	50	158	24.0	76.0	20	node 96	1	1	0.5	0.5
2	node 105	46	112	22.1	53.8	21	node 98	1	0	0.5	0.0
3	node 77	24	88	11.5	42.3	22	node 79	0	0	0.0	0.0
4	node 106	20	68	9.6	32.7	23	node 80	0	0	0.0	0.0
5	node 111	10	58	4.8	27.9	24	node 81	0	0	0.0	0.0
6	node 85	8	50	3.8	24.0	25	node 84	0	0	0.0	0.0
7	node 109	8	42	3.8	20.2	26	node 88	0	0	0.0	0.0
8	node 78	6	36	2.9	17.3	27	node 89	0	0	0.0	0.0
9	node 82	6	30	2.9	14.4	28	node 90	0	0	0.0	0.0
10	node 100	6	24	2.9	11.5	29	node 91	0	0	0.0	0.0
11	node 102	5	19	2.4	9.1	30	node 94	0	0	0.0	0.0
12	node 112	4	15	1.9	7.2	31	node 97	0	0	0.0	0.0
13	node 101	3	12	1.4	5.8	32	node 99	0	0	0.0	0.0
14	node 108	3	9	1.4	4.3	33	node 103	0	0	0.0	0.0
15	node 86	2	7	1.0	3.4	34	node 104	0	0	0.0	0.0
16	node 87	2	5	1.0	2.4	35	node 107	0	0	0.0	0.0
17	node 92	1	4	0.5	1.9	36	node 110	0	0	0.0	0.0
18	node 93	1	3	0.5	1.4	37	node 113	0	0	0.0	0.0
19	node 95	1	2	0.5	1.0						

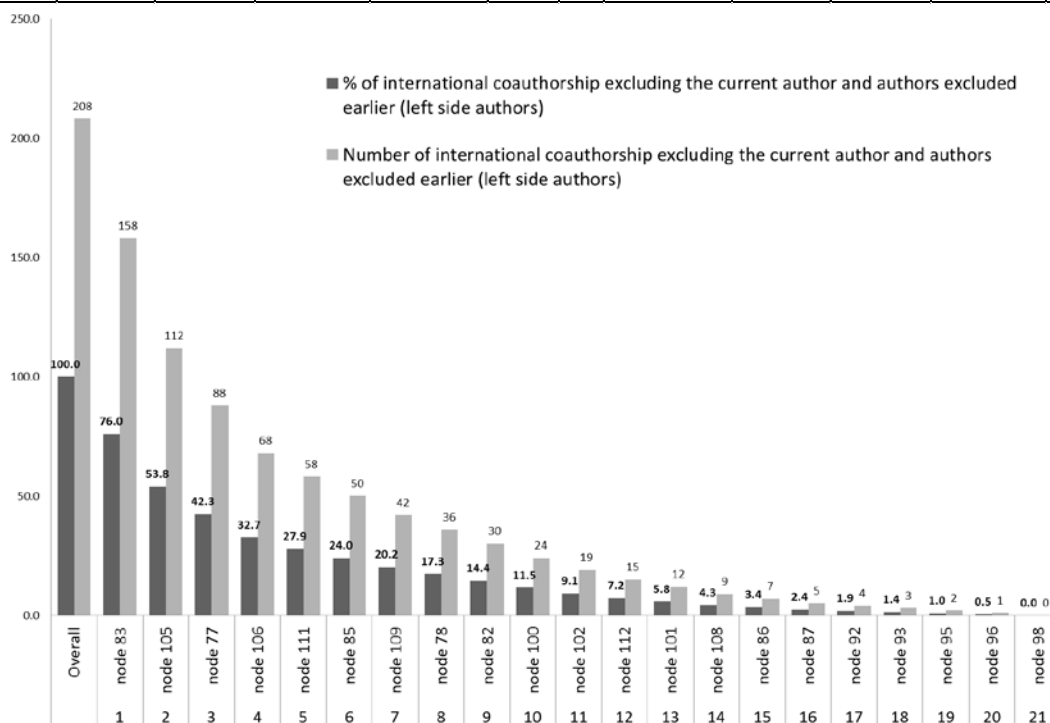


Figure 46. Department of Strategy and Management: International coauthorship based on the sequential faculty members' deletion

5.4. Department of Finance

There are 29 international coauthorships in the Department. The sorted list of faculty members is represented in Table 13. The deletion of 9 out of 13 (approximately, 70% out of 100%) faculty members will lead to the vanishing of the international coauthorship. It is important to notice that the deletion of only 4 out of 13 faculty members (i.e., approx. 30% out of 100%) will bring more than 75% reduction of the departmental international coauthorship. The given results are represented in Figure 47.

Table 13. Department of Finance: International coauthorship by faculty members

	Faculty	number of coauthorship	Overall after exclusion	% out of overall coauthorship	Overall % after exclusion
1	node 126	7	22	24.1	75.9
2	node 119	6	16	20.7	55.2
3	node 117	5	11	17.2	37.9
4	node 125	4	7	13.8	24.1
5	node 114	2	5	6.9	17.2
6	node 115	2	3	6.9	10.3
7	node 116	1	2	3.4	6.9
8	node 118	1	1	3.4	3.4
9	node 122	1	0	3.4	0.0
10	node 120	0	0	0.0	0.0
11	node 121	0	0	0.0	0.0
12	node 123	0	0	0.0	0.0
13	node 124	0	0	0.0	0.0

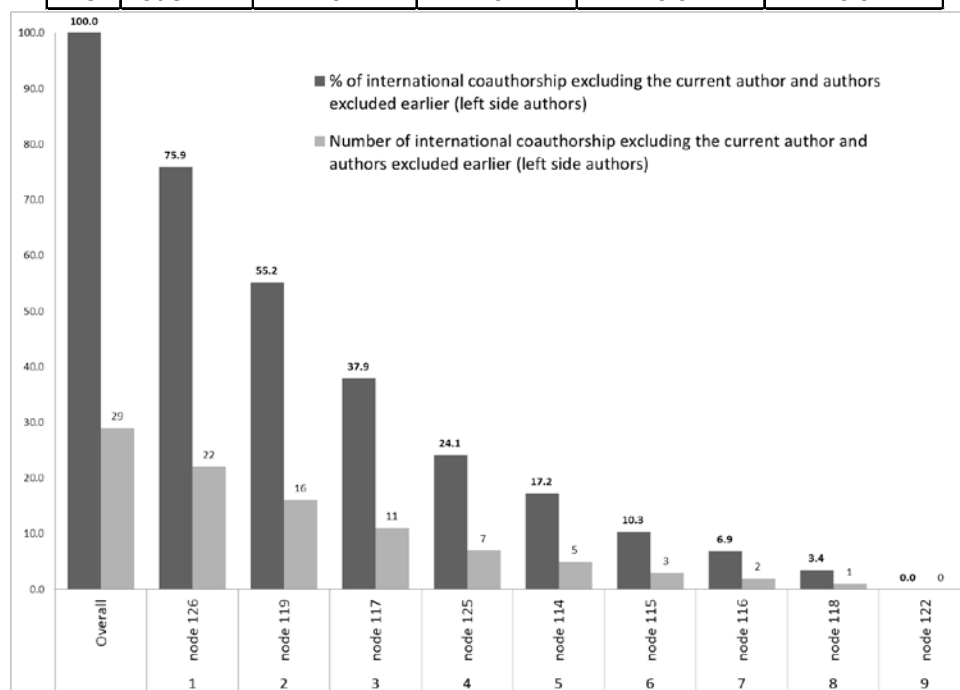


Figure 47. Department of Finance: International coauthorship based on the sequential faculty members' deletion

5.5 Department of Accounting, Auditing and Law

There are 28 international coauthorships in the Department. The sorted list of faculty members is represented in Table 14. The deletion of 6 out of 17 (approximately, 35% out of 100%) faculty members will lead to the vanishing of the international coauthorship. It is important to notice that the deletion of only 3 out of 17 faculty members (i.e., approx. 18% out of 100%) will bring more than 64% reduction of the departmental international coauthorship.

The given results are represented in Figure 48.

Table 14. Department of Accounting, Auditing and Law:
International coauthorship by faculty members

	Faculty	number of coauthorship	Overall after exclusion	% out of overall coauthorship	Overall % after exclusion
1	node 132	7	21	25.0	75.0
2	node 130	6	15	21.4	53.6
3	node 129	5	10	17.9	35.7
4	node 138	5	5	17.9	17.9
5	node 142	3	2	10.7	7.1
6	node 143	2	0	7.1	0.0
7	node 127	0	0	0.0	0.0
8	node 128	0	0	0.0	0.0
9	node 131	0	0	0.0	0.0
10	node 133	0	0	0.0	0.0
11	node 134	0	0	0.0	0.0
12	node 135	0	0	0.0	0.0
13	node 136	0	0	0.0	0.0
14	node 137	0	0	0.0	0.0
15	node 139	0	0	0.0	0.0
16	node 140	0	0	0.0	0.0
17	node 141	0	0	0.0	0.0

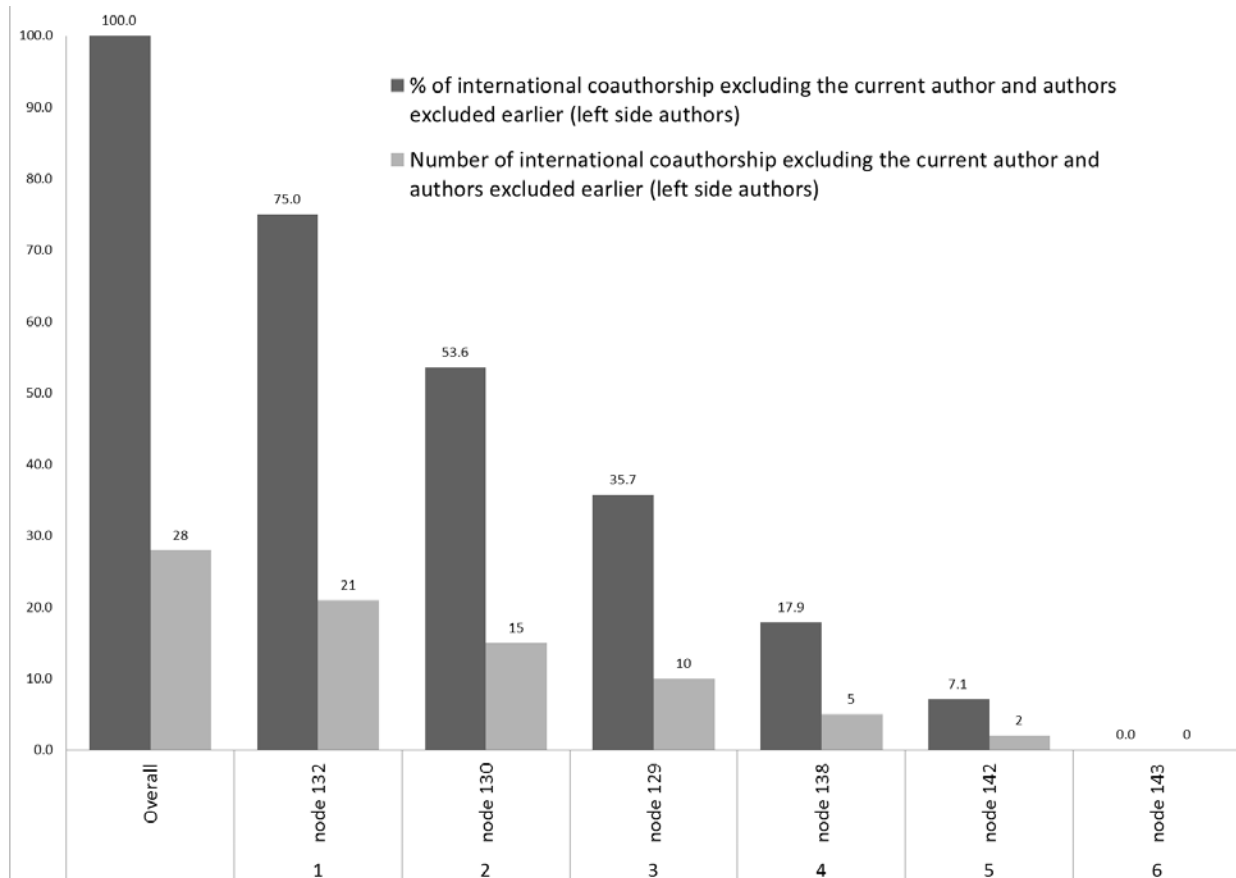


Figure 48. Department of Accounting, Auditing and Law:
International coauthorship based on the sequential faculty members' deletion

5.6 Overall international coauthorship at NHH

The number of the overall international coauthorships is equal to 793. The sorted list of faculty members is represented in Table 15. The deletion of 92 out of 156 (approximately, 59% out of 100%) faculty members will lead to the vanishing of the international coauthorship. It is important to notice that the deletion of only 11 out of 156 faculty members (i.e., approx. 7% out of 100%) will bring almost 50% reduction of the departmental international coauthorship. The given results (in percentage terms) are represented in Figure 49.

Table 15. Overall international coauthorship 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

Table 15 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

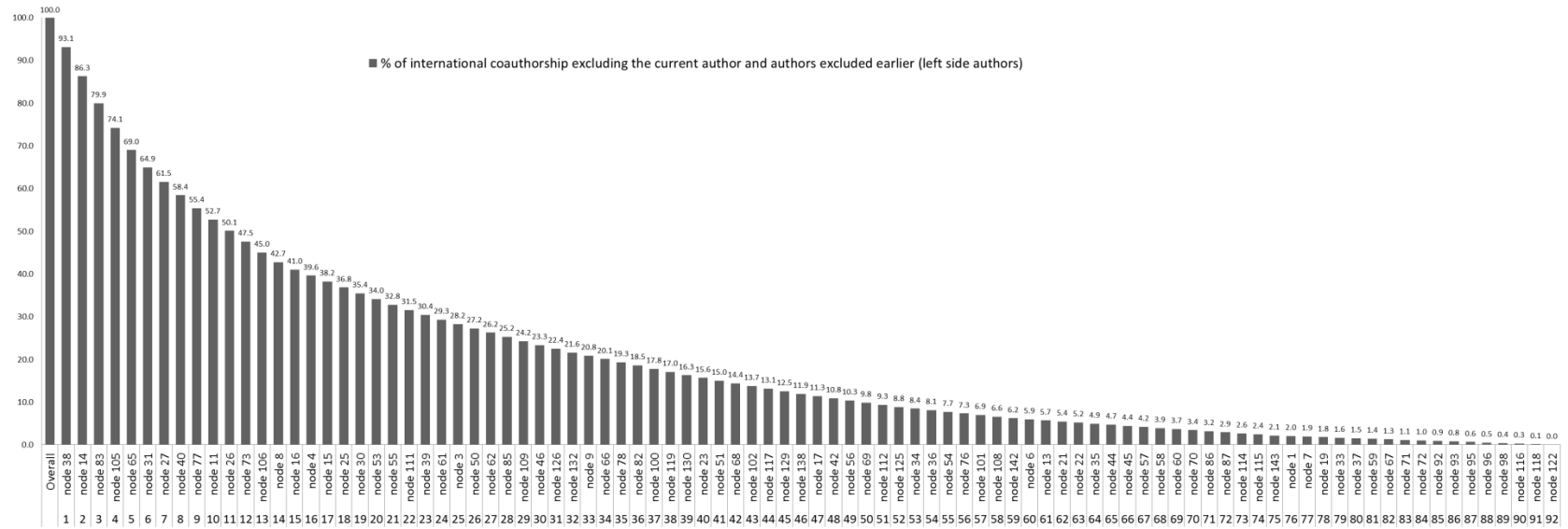


Figure 49. Overall NHH international coauthorship based on the sequential faculty members' deletion

6. THE PUBLICATIONS-BASED ANALYSIS

In this section we analyze the research activity of the NHH 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 the descending order. Next, we start to delete the faculty members from the sorted list one by one in order to track the overall research contribution of the most published faculty members. The results are represented in Table 16 and in Figure 50.

The number of publications of all NHH faculty members is equal to 1278. Based on the results represented in Table 16 and in Figure 50 we detected that the deletion of persons, who have at least 20 publications, will bring almost 50% reduction of the overall NHH faculty member's publications. Specifically, the deletion of 18 out of 156 (approximately, 11% out of 100%) faculty members will lead to the vanishing of 46% of publications.

Table 16. Overall 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

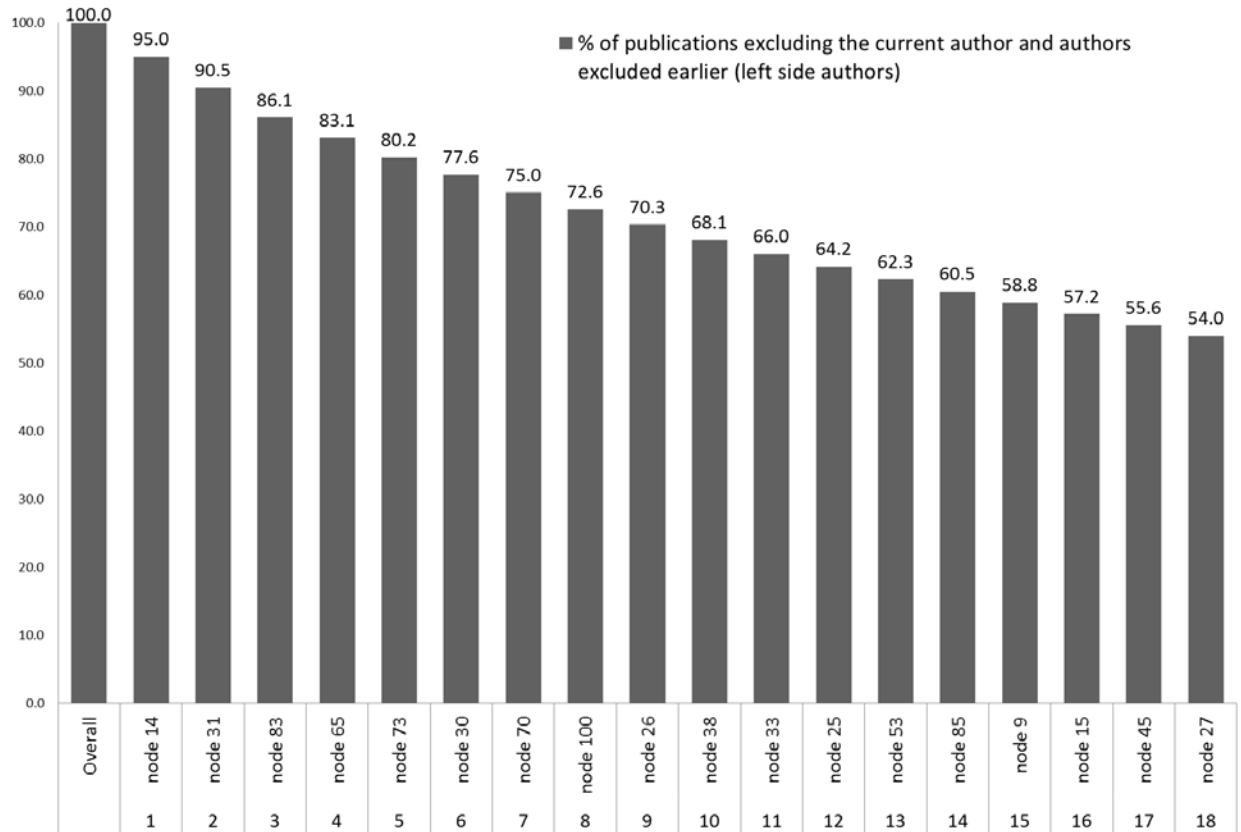


Figure 50. Overall NHH publications based on the sequential deletion of the faculty members who have at least 20 publications registered in *the ISI Web of Science*

7. CONCLUSION

In the given research we constructed the NHH coauthorship network based on the information retrieved from *the ISI Web of Science*. We analyzed the publications in the period 1950 – Spring, 2014 for the current NHH faculty members. The results were represented in tabular and graphical formats. First, we showed the departmental, interdepartmental and external publications for each faculty member. The diversified representation of the overall coauthorship was combined with the information regarding the number of publications done by each faculty member.

Next, we analyzed the strongly connected research groups (i.e., cliques) on the departmental and interdepartmental levels. 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 coauthorship network. In fact, we draw the 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 coauthorship for every department separately and for the overall NHH 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 NHH’s international research collaboration.

Finally, we analyzed the research activity of the NHH 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 the different periods of Spring, 2014. This is due to the fact that the process of extraction, filtering and systemizing of 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. Also, we would like to note that the detailed information in tabular format is available upon request.

We assume that the given research might be helpful for understanding of what is done by NHH faculty members in terms of the 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 faculty. In order to make such an analysis doable all NHH 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 NHHs 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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