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Research Groups' Social Capital: A Clustering Approach

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Abstract

Our purpose in this article is to study the characteristics of a research group's social capital. We proceed from the theoretical distinctions made in the literature on social capital, such as weak against strong ties, structural holes against cohesion and homogeneity against heterogeneity of a group. We assume that research groups differ systematically with respect to the kind of social capital they possess, which has an impact on the scientific performance of the members of these groups.

Social capital of research groups is conceptualized in terms of complete networks. We use the data from the Slovenian study of academic research groups conducted in 2003/2004. Research groups include Ph.D. students, their supervisors, and other researchers. They are representative of the Slovenian research groups, which include Ph.D. students under the "junior researchers" program financed by the Slovenian Ministry of Technology and Higher Education.

We explore the variation in research groups' social capital by using a clustering approach. The analysis reveals three types of research group's social capital: weak social capital, strong social capital of a bonding kind, and strong social capital of a bridging type. Research groups with weak social capital are small, and cooperation ties among group members are weak. Bonding social capital is characteristic for small research groups with strong cooperation ties, which are embedded in a dense network structure. Bridging social capital is found in research groups which consist of a larger number of researchers from different institutions connected with one another with ties of a moderate strength. The network structure in the latter case shows structural holes.

In the last part of the paper, we ask whether scientific performance of Ph.D. students varies according to the social capital of their research groups. We found that students who are involved in research groups with bridging social capital show significantly better performance than students who are members of the groups with either bonding or weak social capital. The relationship between the strength of ties and performance seems to be

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non-linear: it is the moderate strength of social ties and moderate group cohesiveness, which comes along the cooperation across different institutions and disciplines, that is the most beneficial for the performance of Ph.D. students.

1 Introduction

Knowledge is one of the most important resources in today post-industrial societies due to its contribution to growth and development. In this article, we are dealing with a small segment of knowledge creation, which takes place in academic research environment in Slovenia. Research groups consist of several experts from different areas who, besides researching and teaching, also perform the role of supervising the Ph.D. students. Doctoral theses are written in close interrelationship with the research agenda of the group and under the supervision of one of its senior researchers.

The aim of this paper is to study the research group's social capital conceptualized in terms of complete networks. We ask what forms of social capital can be found among Slovenian research groups and what is the impact of these different forms of social capital on the performance of researchers, in particular doctoral students. We explore the variation in research groups' social capital by a using clustering approach.

While human capital is conceptualized as competence, intelligence, and experiences possessed by an individual, social capital refers to the contribution of people to which they have access through social ties in their networks. The term "social" implies that it captures the interaction between people, and "capital" indicates that it should be understood as an asset of the individual, or a group, that comes from relations with others (Rothstein and Stolle, 2003).

Social ties and networks which emerge in research settings are very important for the performance of researchers since they enable access to knowledge and experiences possessed by other researchers within group as well as information on where to go outside the primary research group to obtain help when specific problems emerge. They help in establishing contacts with key professionals in the field and they provide researchers with social support and positive evaluations, which is especially important in the case of young researchers and Ph.D. students.

2 Theoretical background

One of the first definitions of social capital, which belongs to Bourdieu (1983), says that social capital is a sum of resources, actual or virtual, that accrue to an individual or group by virtue of possessing a durable network of more or less institutionalized relationships of mutual acquaintance and recognition. According

to this definition, social capital acquires more than just membership in a certain network. It requires a change of accidental social ties into ties where individuals recognize liabilities to one another.

This distinction between structural and cultural aspects of social capital is made also by Putnam (1993) who understands cultural component as related to trust, norms of reciprocity and mutual understanding in social relationships, and a structural component as patterns of social networks. Both cultural and structural component of social capital are supposed to improve the performance of individuals and society by facilitating coordinated action.

In the literature on social networks, the cultural aspect of social capital is operationalised as strength of social ties assuming that stronger social ties carry more trust and reciprocity than weaker ones, and structural aspect as a pattern of social ties captured by the concepts such as network size, heterogeneity, density and structural holes. Theories of, for example, Coleman (1988), Burt (1992), Granovetter (1973) and Lin (1999) all outline characteristics of social ties and networks responsible for gaining social resources. However, since their arguments were applied in quite dissimilar social contexts, they have very different opinions about which network mechanism underlines the individual or group's success. In what follows, we give a short overview of these theories and apply them into the context of academic environments.

2.1 Strength of ties

Granovetter's work on social capital (1985) traditionally distinguishes between weak and strong ties. According to the author, the strength of tie is a combination of the amount of time spent together, an emotional intensity and intimacy, and the reciprocal services, which characterize the tie. Weak ties as opposed to strong ties were found to be very helpful in providing job information (Granovetter, 1973), since they tend to connect people to more diverse social circles. Furthermore, a spread of job information usually does not require any substantial effort or time investment on the part of the source of information, which is why weak ties, in this case, suffice.

As stated by Hansen (1999), weak ties are beneficent in research work when searching for the sources of information or for transfer of non-codified knowledge, and disturbing when transferring codified or complex knowledge, which is not easy to articulate. Moreover, more complex knowledge transfer requires multiple opportunities for assimilation, as recipients may not acquire the knowledge completely during the first interaction with the source. Weak ties are usually not available immediately when needed. Even if they do, the lack of common language, which is usually established by strong ties, makes the transfer effort in weak ties more difficult. As two people spend more time together, their relationship evolves, usually in the direction of strengthening of their social tie. In

this process, partners develop shared understanding, habits, trust, and language that enable smooth interaction. To put it differently, through repeated interaction two researchers accumulate similar knowledge, which is very important since one of the most common ways that how people learn new ideas is by associating them with what they already know (Cohen and Levinthal, 1990). Successful transfer of knowledge involves connecting previous existing knowledge with new concepts.

More specifically, in knowledge creation, where our knowledge and skills are combined in the way that has never been considered before, information exchange is frequently emerging and scientists often need quick and easy access to others who are willing to engage in discussion (McFayden and Cannella, 2004). Therefore, stronger ties allow such unplanned desire for interaction because of greater motivation to help. During scientific discovery processes, information and know-how are considered sensitive and individuals may share their knowledge cautiously.

2.2 Cohesion

Moving from dyadic relationships to the structure of a network, the traditional view of social capital (Coleman 1988) stresses the positive effects of cohesive networks on the production of social norms and sanctions that facilitate trust, cooperative exchange, and effective coordination between members of a group. A cohesive group can be viewed as one where all members are strongly interconnected with each other.

Cohesion promotes the formation of cooperative norms which define what is considered to be appropriate or inappropriate behaviour and guide individual and group actions (Reagans and McEvily, 2003). As a result, people cooperate with others because cooperation represents a shared value in the network. Cooperative norms assure the knowledge senders that someone will be willing to assist them when they find themselves in a similar position. In this way, they limit increased competition as the successful knowledge transfer creates substitutable points of exchange in the knowledge network. Thus, cohesion affects access to information and in this way lowers asymmetry.

Furthermore, cohesion promotes cooperation by means of reputation. The threat of group sanctions makes trust more likely between people who have mutual friends because of fear that the rumour about their uncooperative behaviour will spread and limit their opportunities for interaction with certain people in the future.

2.3 Group diversity

Another important view on knowledge creation is that some overlap of knowledge across individuals is necessary for internal communication. Yet there are also benefits to diversity of knowledge possessed by members in a group. Heterogeneous teams enjoy an enhanced capacity for creative problem solving as they connect people with different sets of contacts, skills, information, and experiences at one place (Reagans and Zuckerman, 2001). While common knowledge improves communication, commonality should not be carried so far that it diminishes all diversity across individuals since the advantages of diversity can be enormous. A stock of common knowledge is increasing by exposing individuals to multiple perspectives and different ways of framing what they know.

Opinions and behaviours are more homogenous within than between groups. Consequently, people connected to greater number of outside groups are exposed to more worldviews and therefore are more likely to recognize the need for discussion. To illustrate this point, connections with the outside world enhance an individual's capabilities to interpret ideas from people with knowledge from different areas of science into a form that suits his or her knowledge and experiences. It goes also the other way: an individual is capable to transfer what (s)he knows to other people with diverse backgrounds because it is a part of his or her everyday activities. To be accustomed to such practice means that a person is more interesting to others and in this way s(he) is constantly increasing the number of his or her contacts.

Burt (1983) translated the discussion about heterogeneity of individual network into the language of range. Relations have range to the extent that they connect an actor with an extensive diversity of other actors. The simplest concept of diversity is the number of actors directly connected to the individual. Size of a network is significantly related to diversity in social resources. In other words, larger networks generate more solution to a problem simply because an individual can turn to more people for exchanging ideas.

However, diversity of actors, indicating network range, often means more than just mere numbers of actors: it means numerous types of actors. The greater the number of different types of actors to which ego has access, the greater the diversity of information and social support to which (s)he can access. Actors are classified into types according to the position they occupy in the society.

2.4 Constraint

The access to different types of others is not enough to increase the range of the network by itself. Larger range indicates that an individual is able to mobilize different resources embedded in the network which depends also on how members of the network are connected with one another. Although they occupy different

positions, actors who are strongly connected might not increase the diversity of resources since they are very similar by virtue of their frequent communication. Scientists might come from different institutions but still possess very similar knowledge if they are connected with strong ties.

Weaker connections between people or groups represent holes in network structure (Burt 1992). Benefits of social capital in this case come from the access to different knowledge and opportunities created by the lack of social ties between people or groups in the network, which is measured by the concept of constraint. Individuals whose relationships span structural holes broker the flow of information, control the projects, and more easily combine the various points of view. The structural holes do not necessarily mean that members of the network are unaware of one another, but only that they are focused on their own activities and do not attend to the work of other people in the network.

The above theories predict that very different aspects of social networks can contribute to better performance of research groups. However, research groups might not be able to optimize on all of these dimensions at the same time. Just like individual actors, some research groups can be expected to build cohesive networks while others build more diverse networks. In this paper, we study how different network dimensions combine into coherent patterns of social capital.

3 The setting of the empirical study

This research is a part of the international project INSOC (International Network on Social Capital and Performance), which includes Slovenia (Ferligoj, Hlebec, Kogovšek, Mali, Iglič, Matelič, Ziherl), Germany (Hoffmeyer-Zlotnik, Krebs), Belgium (Waege, Ageneessens, De Lange), and Spain (Coenders, Coromina). The aim of the project is to examine the role of research groups' social capital in explaining the performance of doctoral students in different countries (Waege et al., 2000).

The population under study is doctoral students from Slovenia and their research groups. The sampling frame was defined by those students who were in years 1999/2000 and 2000/20001 in the third year of a graduate program. The reason for using this criterion is that these students can be assumed to already have some experiences with publishing and are active members of research networks (Kogovšek et al., 2004). All students are financed by the Ministry of Higher Education and Technology under the auspices of the program called "Junior Researchers" which finances the costs of the graduate study and qualify them for participating in the academic research group.

The list of all doctoral students and their supervisors was obtained from the Ministry. The next step was to contact supervisors in order to define the boundaries of their relevant research groups. These boundaries were defined in

personal interviews with the supervisors in September and October 2003, by the use of three name generators:

- Name all the teaching assistants (or doctoral assistants) whose research is mainly under your supervision.
- Name all the researchers of whom you are formally the mentor and who work on or participate in a research project.
- Name your colleague professors, senior researchers, junior researchers or people working in the private sector with whom you substantially work together on those research projects in which PhD student [name of student] is involved.

We were able to establish contact with 204 supervisors, which presented 86 per cent of all registered supervisors. Among them, 192 were willing to define their research groups and give e-mail addresses of all members of the group. We contacted these persons and asked them to participate in a web survey. In the survey conducted during the period from January to April 2004, we used two different questionnaires; one for the doctoral students and the other for all other members of research groups. The response rates were 61 per cent and 52 per cent respectively.

Based on the questionnaires we can measure relations at different levels of social networks: a) between a PhD student and other members of research group (i.e. ego-centered networks), b) between a PhD student and his/her supervisor (i.e. dyadic relations), and c) between all members of research group (complete networks). In this paper, we focus on complete networks.

For this purpose, we excluded from the sample all the research groups in which either a doctoral student or his/her supervisor did not respond to the questionnaire. In addition, we excluded research groups that did not attain a response rate higher than 60 per cent. With respect to individual members of research groups, we excluded all those who did not fill out the questionnaire and whose frequencies of cooperation were estimated very low by other members of the group. If they did not respond to the questionnaire, but were well integrated into the group, we assumed that cooperation was reciprocal and ascribed them values obtained by other members of the group. However, the problem arises if there are more than one such member of the group who did not respond to the questionnaire since in this case we can not ascribe the values on the basis of the assumption about the reciprocity of the cooperation relations. Such groups were again excluded. For all these reasons, we ended up with 23 research groups. Even though we are left with a smaller number of units (i.e. research groups), the results are meaningful and consistent with those reported by other authors (Matelič et al., 2005; Kogovšek et al., 2004), who performed the analyses at the level of ego-centered networks and dyadic relations.

Table 1: Comparison between samples.

Variables	Chi-square test	Complete networks		Ego-centered networks		Non-respondents	
Gender		Number	Percentages	Number	Percentages	Number	Percentages
Men	0.84 (p-value=0.66)	13	56.5	71	60.7	38	50.7
Women		10	43.5	46	30.3	37	49.3
Total		23	100	117	100	75	100
Science area							
Natural sciences	0.99 (p-value=0.61)	18	78.3	94	80.3	61	81.3
Social sciences		5	21.7	23	19.7	14	18.7
Total		23	100	117	100	75	100
PhD students' year of employment in current department							
Before 2000	0.99 (p-value=0.61)	2	8.7	14	12.7		
Year 2000		19	82.6	89	80.9		
After 2000		2	8.7	7	6,4		
Total		23	100	110	110		

In order to avoid incorrect generalizations of our results we also made a comparison of the samples used in the analyses at the level of complete networks, ego-centred networks and non-respondents, according to the gender, scientific discipline and the year of employment of the graduate student in the research organization (Table 1). Significant differences among the samples would indicate that our-sample is non-representative and that estimates are biased. Chi-square statistics show that there are no significant differences between the samples.

4 Operationalisation of the variables

To measure research groups' social capital we defined several measures of complete networks which capture the concepts discussed in the theoretical section: strength of ties, cohesion, diversity and constraint.

Strength of ties was measured as the average frequency of cooperation between PhD student and all other members of his or her research group (the list of the members of the research group defined by supervisor was given):

- "Consider all situations of the past year (that is, since 1 November 2002) in which you co-operated with your colleagues, e.g., working on the same project, solving problems together and so on. Minor advice does not belong to this type of co-operation. How often have you been co-operating with each of your colleagues?"

The responses were coded on a scale from 1 (no cooperation in the past year) to 8 (we cooperated on a daily basis). If the respondent did not know a person named in the question, his or her relationship to this person was coded as 0.

We measured *cohesion* as the average frequency of cooperation between all members of the research group ("cohesion"), again on the scale from 0 (do not know a person) or 1 (no cooperation in the past year) to 8 (cooperation on a daily basis).

In order to measure *diversity* of the research group we used the following information:

- the size of the research group ("size"),
- the number of people with whom doctoral student cooperated outside the original research group ("others"),
- the number of different organizations which members of the research group came from ("institutions").

Constraint was measured by Burt's index of constraints (1992), which implies that the number of structural holes lowers proportionally with increasing the strength of direct and indirect ties:

$$C_i = \sum_j (p_{ij} + \sum_q p_{iq} p_{qj}),$$

where p_{ij} is the proportional strength of the tie of the person *i* with the person *j* and it is defined as:

$$p_{ij} = \frac{z_{ij} + z_{ji}}{\left[\sum_j z_{ij} + z_{ji}\right]},$$

where z_{ij} is an interaction between person *i* and *j* (in our case this means the frequency of cooperation on scale 1-8 or 0 if person *i* does not know person *j*).

A person *i* is constrained to extend that (s)he has made a large investment of time and energy to reach *j*. Furthermore, another *i*'s contact *q*, in whom the person *i* invested a large proportion of his network time and energy, has invested heavily in a relationship with person *j*. Even if a person *i* withdraws from direct relationship with *j*, portions of his/her other relations leads him/her back to *j*. In other words, person *j* is surrounded by few structural holes. A sum of all individual's direct and indirect ties is aggregate measure of constraints C_i.

5 Results

We identified different types of research group's social capital by using a clustering approach. Cluster analysis deals with the grouping of units into clusters so that those within a cluster are as similar to each other as possible according to measured variables, whereas units in different clusters are as dissimilar as possible (Ferligoj, 1989). The set of obtained clusters is called a clustering.

In order to produce hierarchical clusters we used Ward's method, which is as one of the most often used in the literature (Ferligoj, 1989). The variables were standardized in usual way – we subtracted the mean of the variable from individual

variable's value and divided it by its standard deviation – to make sure that all variables got equal weight in the clustering procedure. To measure the dissimilarity between two units (research groups) we chose Euclidian distance.

The dendrogram in Figure 1 presents the process of fusing of research groups into clusters. It reveals three clusters. In Appendix 2 to 4 we provide graphical representations of all 23 research networks as they fall into three clusters (see also Appendix 1 for the groups' scores on different network variables used in the analysis). Triangles represent supervisors, parallelograms junior researchers, and circles stand for other members of the group. The boldness of the line indicates the strength of tie (frequency of cooperation) between members of the group.

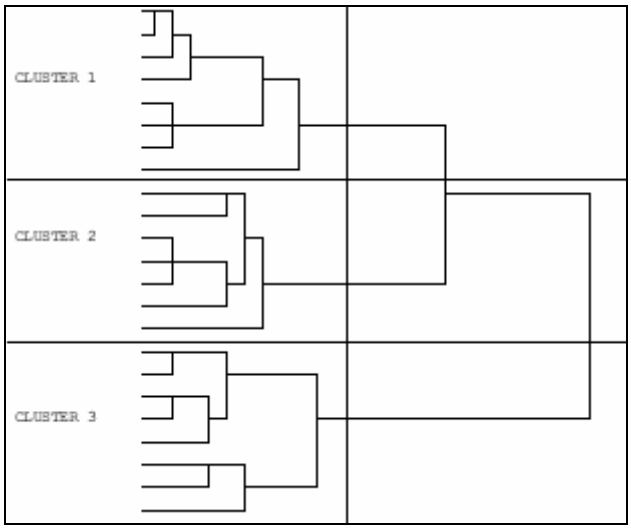


Figure 1: Dendrogram.

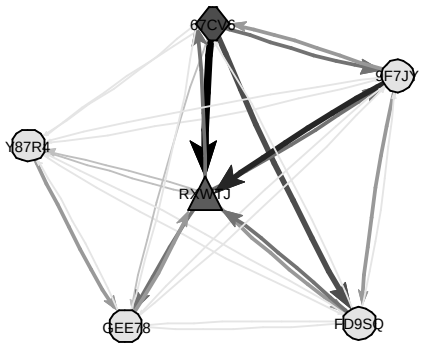
In Table 2, the means of all the network variables were used in the analysis are compared across the clusters.

Table 2: The characteristics of clusters.

Clusters		Tie strength	Cohesion	Size	Others	Institutions	Constraint
1 - Weak social capital cluster	Mean	***1,67***	***2,36***	***5,5***	***0,5***	***1,88***	***0,73***
	Std.dev.	1,08	1,05	1,6	0,75	0,64	0,13
2 - Bonding social capital cluster	Mean	***3,66***	***4,47***	***4,14***	***2,57***	***1,71***	***0,84***
	Std.dev.	1,97	0,86	0,69	1,51	0,75	0,12
3 - Bridging social capital cluster	Mean	***2,69***	***3,07***	***8,25***	***4,13***	***3,5***	***0,55***
	Std.dev.	0,83	1,02	1,91	2,99	0,75	0,09
Total	Mean	***2,64***	***3,25***	***6,04***	***2,39***	***2,39***	***0,71***
	Std.dev.	1,52	1,29	2,26	2,46	1,07	0,16

The first cluster includes research groups which are small and where PhD students and other researchers only rarely cooperate with one another, or with researchers outside the "primary" group. Most of researchers come from the same institution. All network variables have low values which is why we label this cluster as *weak social capital*.

A typical representative of the first cluster is research group 1e (see Figure 2 and Appendix 2), where the average frequency of cooperation among the six members of the group is a few times a year. Junior researcher in this group has not tried to cooperate neither with the members of research group nor with any person outside the "primary" group in the year before interviewing. The estimated index of constraints is 0.78.



Average frequency of cooperation	Few times a year
Average frequency of cooperation between PhD students and other members	Not in year before interviewing
Number of »outside« people with who PhD student cooperates	None
Number of different instititutions	1
Size of research group	6
Index of constraints	0,78

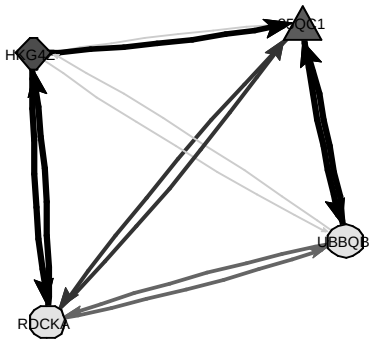
Figure 2: Typical representative of cluster 1.

In the second cluster we find research groups which are very small but with well developed cooperation. The average strength of ties between PhD student and members of their research group is the highest. Although the members of the research group come from the same institution, PhD students also cooperate with some researchers outside the "primary" group. The overall cohesion of the research group is the highest. We label this cluster as *bonding social capital*.

A typical representative of the second cluster is research group 2e (see Figure 3). The research group consists of four members who come from the same institution. They cooperate with each other approximately once a month, while PhD student cooperates with them on average few times a year. Moreover, junior researcher from this group has cooperated with three people outside his research group in the year before interviewing. The score for index of constraints is 0.85.

The third cluster consists of research groups which are large and diverse. They include researchers from different institutions. Besides being exposed to very diverse internal environment, PhD students also maintain numerous cooperation ties with people outside the original group. The average strength of ties between PhD student and other members of the group is moderate indicating that his7her cooperation relations are spread among the larger number of colleagues. The network structure shows structural holes meaning that researchers are often

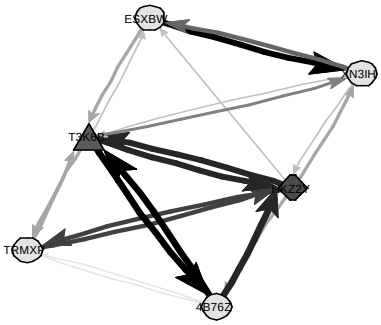
brokers between unconnected parts of their networks. Due to the institutional diversity and structural holes that characterize this cluster, we label it as *bridging social capital*.[4]



Average frequency of cooperation	Once a month
Average frequency of cooperation between PhD students and other members	Few times a year
Number of »outside« people with who PhD student cooperates	3
Number of different instititutions	1
Size of research group	4
Index of constraints	0,85

Figure 3: Typical representative of cluster 2.

The third cluster is best represented by research group 3e. This research group has eight members from four different institutions who cooperate with one another once or few times a year. The average frequency of cooperation between PhD student and other members is few times a year. Besides the ties to group members,a junior researcher also listed his(her) involvement with two other people with whom s(he) has cooperated during the last year. His or her index of constraints is 0.56.



Average frequency of cooperation	Once/few times a year
Average frequency of cooperation between PhD students and other members	Few times a year
Number of »outside« people with who PhD student cooperates	2
Number of different instititutions	4
Size of research group	8
Index of constraints	0,56

Figure 4: Typical representative of cluster 3.

[4] The three types of social capital found among the Slovenian research groups correspond to more broadly defined forms of social capital discussed, for example, by Putnam (2002) who makes a difference between bonding and bridging social capital, or Newton (2001) who distinguishes between thick and thin social capital.

6 The performance of doctoral students

Writing articles and doctoral thesis are not solo activities as they acquire exchanging ideas and cooperating with others. PhD students' success is likely to depend on network characteristics of their research group, in addition to the individual characteristics and motivation. In this section, we ask whether scientific performance of PhD students varies according to the three forms of social capital delineated in the previous section: weak, bonding and bridging social capital.

Authors have different opinions about which network characteristics are beneficial for individual's scientific performance. According to Hansen (1999) strong ties enables smooth interaction between two people, as they develop a shared language (understanding) in time. Similarly, cohesive networks promote exchange of information and effective coordination between people due to group pressure and strong collective identity.

On the other hand, Burt (1992) states that people constrained by strong direct and indirect ties have to devote a lot of time and effort to maintain the relationships, even though they might not get anything from them. Therefore, they miss the opportunities to create new ties, which could contribute new resources and social support. In addition, cohesion implies that members of a group have the same pieces of information which lower their value. In time, strongly interconnected people develop similar behaviour and thinking which do not bring out new challenges.

Considering all above, the latest discussions among social networks researchers combine these two views and stress the non-linear function between strength of ties or cohesion and performance (for example, McFadyen and Cannela, 2004). Too weak ties do not enable effective exchange of information, since no basic trust could be developed between people in the group. On the contrary, too strong ties could be a too large commitment of an individual to others. Thus, the optimal strength of ties should be somewhere in the middle, so that an individual would be able to do his/her solo activities and in the same time get the necessary information needed for completing his/her work.

To measure scientific performance, each PhD student was asked about his/her publications and participation at the conferences and workshop. The publications were categorized in the following way (see Coenders and Coromina, 2004; Kogovšek et al., 2004):

- articles in international journals (with/without reviewers), books, book chapters - with reviewers (int_art),
- articles, papers in proceedings - with reviewers (pub_rev),
- articles, books, book chapters, papers in proceedings, internal research reports- without reviewers (pub_norm),
- participations at international/national conferences/workshops – with/without presentations (pap_conf).

The index of performance ("IP") was defined so that it gives weights according to the importance of the publication:

$$IP = 2*(int\_art) + 2*(pub\_rev) + (pub\_norm) + (pap\_conf).$$

There is no difference in the performance of Slovenian PhD students according to the area of science (natural science or social science; t-test = -0.969, p-value = 0.343) or gender of the student (t-test = 1.758, p-value = 0.199). These background variables do not effect the scientific performance of the PhD students. But, as can be seen from table 3, the networks or micro-context of scientific production matters. The performance of PhD students clearly varies across the three clusters. It follows from the table 3 that PhD students who are included in research groups with bridging type of social capital are the most successful. Their average index of performance is 22.13, which is much higher than in clusters with either weak or bonding type of social capital (6.63 and 9.29 respectively).

Table 3: Average index of PhD students' performance in three clusters.

Clusters		Index of performance
1 – Weak social capital cluster	Mean	***6,63***
	Std.dev.	5,65
2 – Bonding social capital cluster	Mean	***9,29***
	Std.dev.	4,07
3 – Bridging social capital cluster	Mean	***22,13***
	Std.dev.	8,87
Total	Mean	***12,83***
	Std.dev.	9,44

To test whether the average PhD students' performance differs between the three clusters, we performed ANOVA and Bonferroni's post hoc tests. From Table 4 we can conclude that there is a significant difference in performance between cluster 3 (the most successful cluster) and clusters 1 and 2, whereas difference between cluster 1 and cluster 2 is not significant.

Table 4: ANOVA and Bonferonni's post hoc tests.

		F-test	Significance
ANOVA		12.44	0.00
Bonferroni's post hoc tests		Mean difference	Significance
Cluster 1	2	-2.66	1.000
	3	-15.50	.000
Cluster 2	1	2.66	1.000
	3	-12.84	.004
Cluster 3	1	15.50	.000
	2	12.84	.004

Comparing the average strength of ties and cohesion in three clusters, we can see that their influence on PhD student's performance could, in fact, describe a non-linear function. The most successful students are found in cluster with bridging social capital where the strength of ties and cohesion are moderate, while less successful students are members of research groups with either weak or bonding social capital. In these clusters the strength of ties and cohesion take the lowest or the highest values. Strength of tie seems to be important to a certain point since it assures the access to information, ideas and social resources. Nevertheless, there exists a turning point where the relationship between strength of ties or cohesion and success becomes negative.

Further examination of the relationship between research group's social capital and performance also reveals that the most successful PhD students are included in research groups that are large, consist of researchers from different institutions, include many outside contacts, and have network structure characterized with structural holes. Research groups from cluster three have the highest average scores on all these variables. Thus, in addition to maintaining moderate strength of tie with their colleagues, researchers also need to work in a diverse academic environment and cooperate with numerous other researchers in order to achieve the best performance.

7 Conclusions

We explored the variation in the social capital of Slovenian academic research groups which consist of researchers, PhD students and their supervisors. The analysis reveals three types of social capital which correspond broadly to the forms of social capital discussed in the literature: weak social capital, strong social capital of a bonding kind, and strong social capital of a bridging type. Research groups with weak social capital are small and cooperation ties among group members are weak. Bonding social capital is characteristic for small research groups with strong cooperation ties, which are embedded in a dense network structure. Bridging social capital is found in research groups which consist of a larger number of researchers from different institutions connected with one another with ties of a moderate strength. The network structure in this case shows structural holes.

Slovenian research groups are not characterized by a dominant form of social capital. The three types of social capital are rather equally spread among the research groups. They are also not research field specific. Both natural and social sciences research groups are very diverse with respect to their social capital. Moreover, in the natural and social sciences alike, the performance of PhD students is associated with the research group's social capital. Research groups with bridging social capital seem to present much more stimulating academic environment than either groups with weak or bonding kind of social capital. The

reasons for this lie in the size of the networks and diversity of the members of research groups who come from different institutions and thereby provide Ph.D. students with very different ideas, approaches, resources, and professional contacts. In order to result in good performance, this academic cooperation does not need to be embedded in strong ties. A moderate strength of ties seems to suffice.

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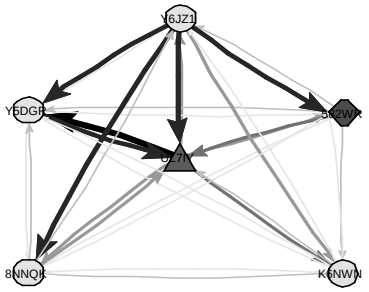
Appendix 1: Research group's scores for network variables used in hierarchical clustering analysis

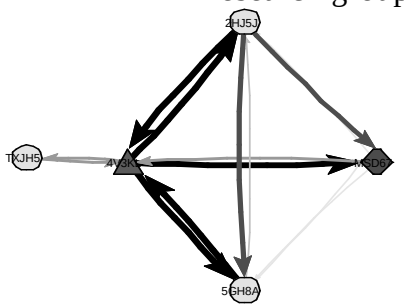
Label of a research group	Cohesion	Strength of ties	Institutions	Size	Constraints	Others
1a	3,05	2	3	7	0,64	1
1b	3,42	1,33	2	5	0,92	1
1c	2,2	2,25	2	6	0,62	0
1d	2,33	3,67	2	5	0,61	0
1e	3,08	1	1	6	0,78	0
1f	2,33	1,17	2	6	0,83	0
1g	2,47	2	2	7	0,59	0
1h	0	0	1	2	0,86	2
2a	4	7	2	3	0,9	0
2b	5,67	1,5	1	4	0,96	1
2c	5,75	5,17	1	5	0,67	4
2d	3,67	4,5	2	4	0,77	3
2e	4	3	1	4	0,85	3
2f	4	2	3	4	1	4
2g	4,25	2,5	2	5	0,71	3
3a	4	2,6	3	10	0,57	3
3b	3,5	2,88	4	6	0,66	7
3c	2,1	4	3	7	0,52	1
3d	1,79	2,83	4	10	0,41	8
3e	2,4	3,63	4	8	0,56	2
3f	2,5	2,25	4	11	0,44	2
3g	3,65	1,5	2	6	0,64	8
3h	4,67	1,9	4	8	0,61	2

Appendix 2: Cooperation networks for Cluster 1 – "weak social capital cluster"

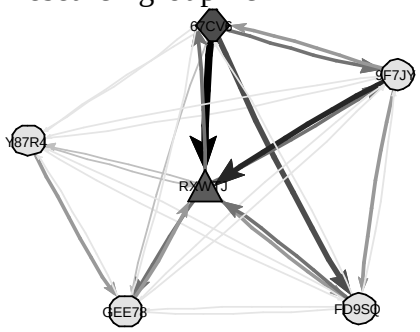
Research group 1a



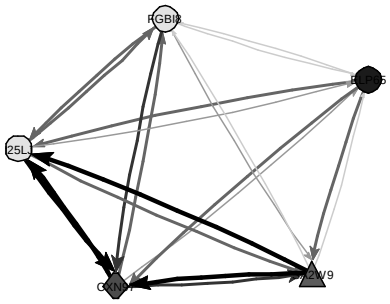
Research group 1b



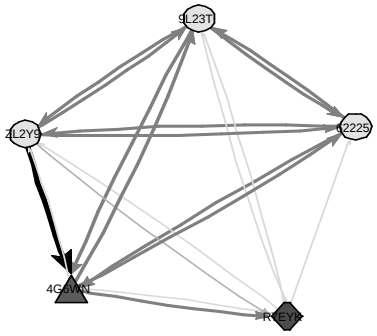
Research group 1c



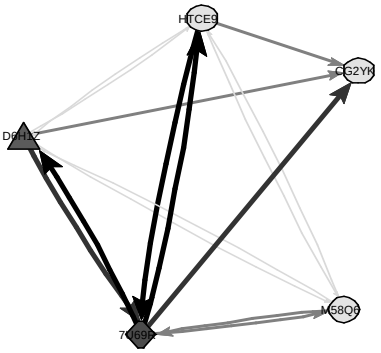
Research group 1d



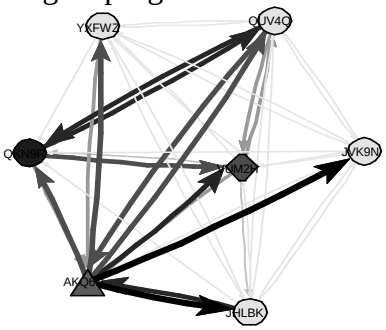
Research group 1e



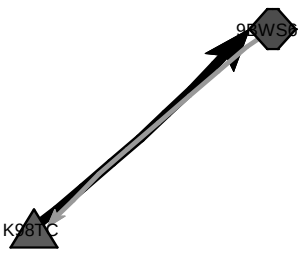
Research group 1f



Research group 1g

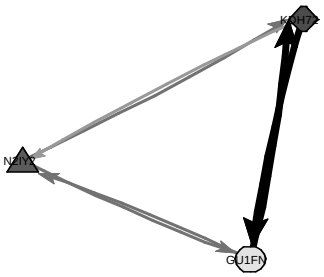


Research group 1h

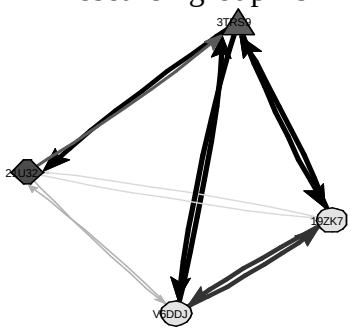


Appendix 3: Cooperation networks for Cluster 2 – "bonding social capital cluster"

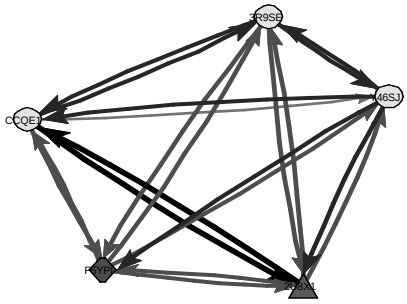
Research group 2a



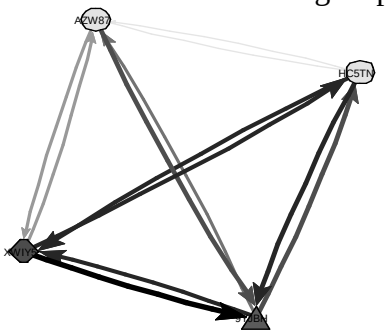
Research group 2b



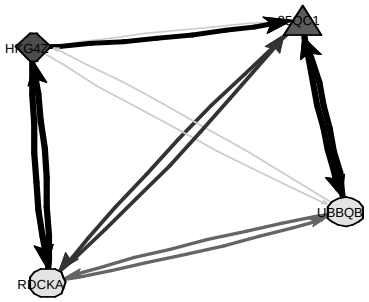
Research group 2c



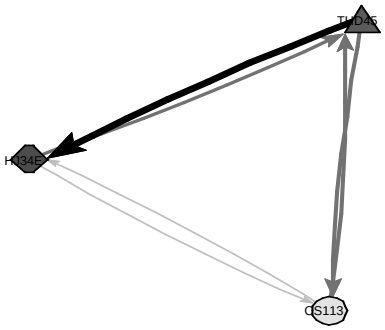
Research group 2d



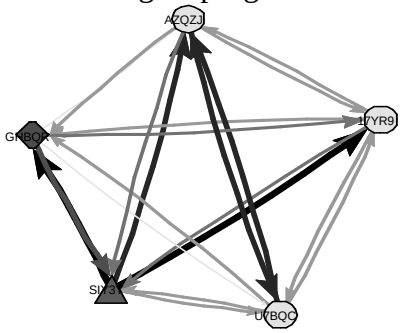
Research group 2e



Research group 2f

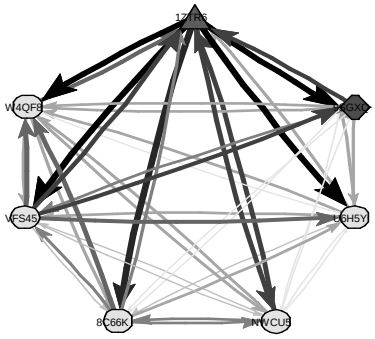


Research group 2g

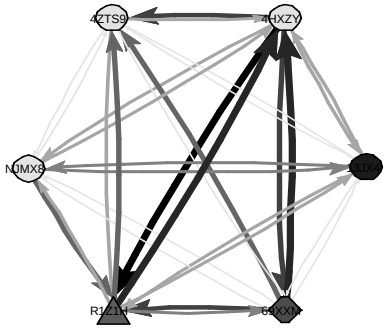


Appendix 4: Cooperation networks for Cluster 3 – "bridging social capital cluster"

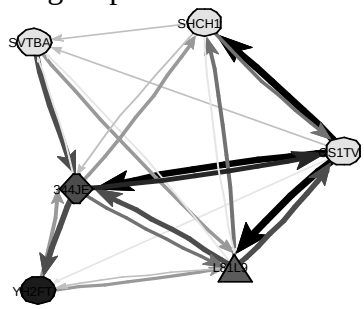
Research group 3a



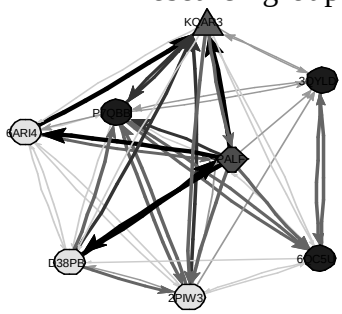
Research group 3b



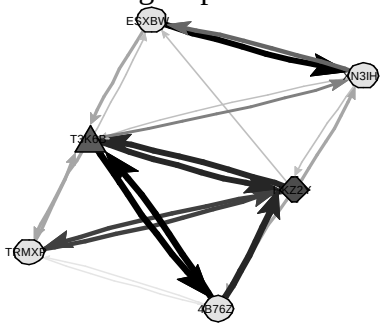
Research group 3c



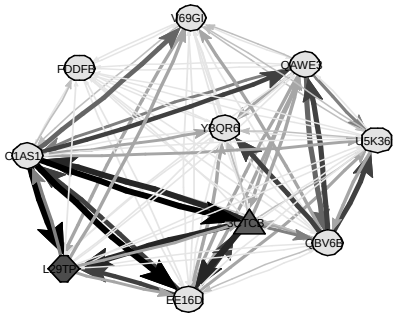
Research group 3d



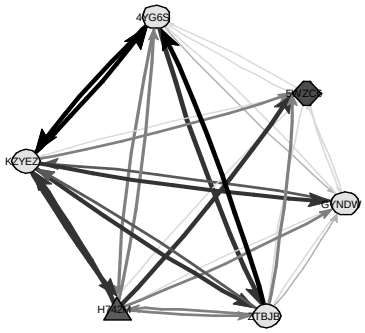
Research group 3e



Research group 3f



Research group 3g



Research group 3h