Connecting Research, Higher Education and Business: Implications for Innovation

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DEVELOPING INNOVATION NETWORKS might positively influence research and development performance, boost creation of new knowledge, and increase technology transfer and export of high technology products in a country. In our study, we analysed some of the networking mechanisms in Slovenia, which have been introduced to create innovation synergies between research, higher education, and business sector: Competence Centres, Centres of Excellence, and Development Centres. Through the analysis we confirmed the basic assumptions stemming from the theory of networking. We found that: innovative clusters (or groups) usually consist of members who come from similar disciplines or industries, the history of cooperation represents an important element of innovative cooperation, and groups are usually geographically concentrated. Besides, we confirmed and revealed some problems related to Slovenian technological development and consequently economic performance.

Key Words: networking; innovation; social network analysis

INTRODUCTION

Research Opportunities

In 2009, Slovenia has been ranked as a European innovation follower (Ministrstvo za visoko šolstvo, znanost in tehnologijo 2010), which means that the volume of innovation activity of Slovenian companies

has grown; however, the level of such activities in the country is still relatively low. In addition to some relative advantages, such as the quality of human resources and the existence of entrepreneurship support services, the key weaknesses of the Slovenian innovation environment
[66] relate particularly to technological achievements in terms of patenting, commercialisation of new knowledge, exporting of high-tech products, and the transfer of high technology.

In Slovenia, the number of European patent applications per million inhabitants reaches only 44% of the EU27 average. The situation regarding Slovenian patent applications in the North American market is even worse, because they reach only 13% of the EU27 average. Slightly better is the situation regarding the European high-tech patents applications – Slovenia has achieved 61% of the EU27 average. Slovenia is also quite weak in the field of high-tech exports. The export share of high-tech products in total exports reaches only a 28% share of exports of the EU27 average (see http://epp.eurostat.ec.europa.eu). Besides, Slovenia's spending for R&D reaches 1.9% of the Gross Domestic Product (GDP). This is 0.1 percentage points less than the EU27 average (see http://epp.eurostat.ec.europa.eu). Total R&D expenditure per capita in Slovenia is rather modest, since it reaches only 68% of the EU27 average. Furthermore, in higher education (HEI) sector the average reaches only 48%. The situation is slightly better in the business sector, but its R&D expenditure is still only at 71% of the EU27 average. Nevertheless, in recent years, the Slovenian R&D expenditure has been rising. For example, the volume of total expenditure rose from about 300 million EUR to about 600 million EUR since 2001. Most of these funds were invested by the Slovenian business sector (387 million), while a slightly smaller proportion was invested in R&D activities by the Slovenian government (187 million). We believe that to encourage the volume and the quality of innovation and ensure the protection and commercial use of new knowledge, it is important to increase the scope of research and development (R&D) activities, especially by encouraging the establishment of innovation networks including key actors of R&D – higher education institutions (HEI), public research organizations (RO), and companies (Vidulin and Gams 2006).

Innovation Networking

In the studies of entrepreneurial networking some authors focus primarily on the horizontal links and cooperation between small to medium-sized enterprises (SMEs) (Tavčar and Dermol 2012). Marshall (1961) named such kind of networking 'the industrial districts.' [67] Other authors highlight the links between big companies and their suppliers, usually smaller firms (Marceau 1999; Vukasovič 2012). In such cases, the hierarchical relationships or clusters in vertical supply chain appear. Links can also be developed among companies, which base their businesses on the same kind of resources. Furthermore, relations also emerge among companies involved in joint innovation or in joint production (Marceau 1999). In such cases innovation clusters appear.

Businesses rarely innovate in isolation. Innovation can actually be defined as a learning process, which requires the exchange of knowledge and a high level of interaction between different actors in the network or value chain (Roelandt and Hertog 1999). Hidalgo and Albors (2008) summarize the core features of an innovation process in a knowledge-driven economy: (i) a problem-solving, (ii) interactive process involving relationships between firms with different actors, that (iii) arises from different learning situations, such as: learning-by-using, learning-by-doing or learning-by-sharing, and as such (iv) involves the exchange of codified and tacit knowledge, and where (v) interdependence between actors generates an innovative system or an innovation cluster. Innovation activities require the involvement of several parties combining their specialized yet complementary knowledge (Roelandt and Hertog 1999). Active participants in innovation clusters are often companies (large and small), academic research institutions, as well as HEI and public or private providers of education and training (Roelandt and Hertog 1999; Košir and Bezenšek 2009; Natek and Lesjak 2013).

Researchers focused on innovation networks emphasise the importance of geographical proximity between the members of the network. Proximity encourages interaction and is an important part of network dynamics. As noted by Marceau (1999), operating in the geographic vicinity is easier if there are various HEI or research organizations in-

volved as well. However, geographical proximity is not the only criterion for successful networking. Knowledge sharing and cooperation between organizations in networks are based on trust and shared experience, which is often exercised informally and through direct contacts
[68] between individuals. Research shows that the bulk of the knowledge transfer is self-organized and implemented directly among the employees, professionals, and managers (Spielkamp and Vopel 1999; Starček and Trunk 2013). Antončič, Ruzzier, and Bratkovič (2007), in addition to geographic concentration, emphasise the importance of the existence of support institutions in terms of infrastructure (e. g. information centres, computer networks), the involvement of HEI and research organisations, and also underline the importance of prior cooperation between network members and the reputation of key members of the network. Spielkamp and Vopel (1999) further note that companies often join the network on the basis of belonging to the same industry (e. g. information technology, food industry, financial industry etc). They emphasize that innovation clusters tend to include bigger companies.

R&D *Integration Mechanisms in Slovenia*

According to the data on innovation activities in Slovenia in 2006, approximately half of the innovation active companies were involved in R&D cooperation with some other organisation. Less than 25% of such companies cooperate with HEI and approximately 15% of them cooperate with public RO (Ministrstvo za visoko šolstvo, znanost in tehnologijo 2010). Relative modesty of networking activities is also acknowledged by the research on networking for lifelong learning (Natek et al. 2010).

The Slovenian government encourages innovation networking with some financial incentives. For the years from 2009 to 2015, the government plans to encourage R&D activities through three key mechanisms of R&D integration (Competence Centres – CC, Centres of Excellence – CE, and Development Centres – DC) in the amount of about 314 millions of EUR. This amount of money displays a relatively high importance of these three mechanisms; namely, this amount exceeds the volume of almost two years of governmental investment

in R&D in Slovenia. The Ministry responsible for higher education and science, together with the European Regional Development Fund, supports research and networking through CC in the amount of 45 million EUR in the years 2010–3 and through CE in the amount of 84 million EUR in the years from 2009 to 2013. The Ministry of Economy, in cooperation with the European Regional Development Fund, encourages research and networking in the range of 185 million in the period of 2010–5 investing in the construction and operation of DC. [69]

With our study, we identify the centres of the Slovenian R&D and innovation. Additionally, we attempt to identify the research areas within which the Slovenian companies, public RO and HEI most often cooperate.

RESEARCH METHODS

The data about companies, HEI, RO, and other organisations cooperating in CC, CO, and RC were obtained from the internet. Additional information related to research activities and performance of organisations' researchers and research groups was collected from the web pages of IZUM (Institute of Information Science). We were especially interested in the number of registered researchers in the organisation, their SICRIS points, measurement of their research performance, number of citations (in journals indexed by SCI-Expanded, SSCI, and A&HCI), and in the number of registered patents in an organisation. Eventually, organisations were clustered into twelve Slovenian statistical regions.

Special emphasis in our analysis was on cooperation among analysed organisations. Therefore, we used the network analytic techniques. These statistical methods are focused on the characteristics of relations, rather than on the characteristics of individual entities. Nevertheless, the examination of the structure of any given network is a formidable task that includes significant hurdles associated with the issue of how to define and measure links or relationships (Jackson 2008). The relation in our network was defined in the following way: two organisations are in the relationship if they are involved in the same CC, CE or RC. Thus, the defined relation is symmetrical and the network is undirected. Furthermore, the pair of organisations could be involved in various CCs, CEs or DC's, thus the network is considered

as weighted. The weight on each edge (undirected tie between entities in the network) is determined by the number of CCs, CEs or DCs in which the organisations are included.

The R package (http://www.r-project.org) software was used for
[70] descriptive analysis and algorithms for the preparation of network. Network analysis was carried out by Pajek (Slovenian word for Spider) (Batagelj and Mrvar 2002; http://vlado.fmf.uni-lj.si/pub/networks/pajek/). Pajek is a program for the analysis and visualisation of large networks (Wasserman and Faust 1994). Both programs are open source programs and thus freely available for non-commercial use.

RESULTS OF THE STUDY

The Networks in Slovenian R&D

The basic network consists of 336 organisations, grouped in 34 CC, CE, and DC with 3697 edges among them. The vast majority of edges (3527 or 95.4%) has the value of 1, the remaining 170 edges have higher values. The Institute Jozef Stefan (IJS) has the most valued edges, since it cooperates with the Faculty of Electrical Engineering in Ljubljana (UL FE) in seven different CC, CE, and DC, and with the Faculty of Electrical Engineering and Computer Science in Maribor (UM FERI) and Lek (Slovenian pharmaceutical company) in five different CC, CE, and DC. Furthermore, UL FE and UM FERI are together in six aggregations. All other values of edges in the network are lower.

Due to the specific definition of relation, we decided to remove all the edges with values less than 2 from the network. Indeed, organizations that participate in only one CC, CE or DC are not difficult to trace, but we were more interested in more densely connected innovation network. When we defined our network in such way, only one weak component (group of related organizations) remained with 58 vertices (members). According to the definition of (sub) network, each organization in the (sub) network is a member of at least two CC, CE or DC together with another organization from this (sub) network. The network is graphically presented in figure 1. The vertices representing the organizations are painted according to the region to which the organisations belong. Throughout the paper, the region from which a company is originating is displayed in the square bracket.

It appears that organizations from Central Slovenia region dominate among the participating organizations (black circle shaped vertices; [10]), a surprisingly large number of organisations involved in the original network come from the small Gorizia Region (gray circle shaped vertices; [11]). However, there are very few members of this network from Podravska Region with the second largest university in Slovenia (black square shaped vertices; [3]). [71]

R&D *Cooperation Between Statistical Regions in Slovenia*

In the following steps of our study, we compressed the organizations by the region they belong to, which resulted in a network with 12 vertices – statistical regions in Slovenia (see figure 2). We wanted to examine to what extent the different regions in Slovenia cooperate in the area of R&D. After we removed all the loops (links within regions), we normalised the rest of the edges by dividing the edges' value with the square root of the multiplied numbers of organizations in both regions. The size of the vertices (circle or square shaped) indicating the regions is proportional to the number of inhabitants in each region. As shown in figure 1, the Slovenian R&D is rather centralised and located mainly in the Central Slovenian Region. This is of course expected, since the largest Slovenian university and most of the major high-tech companies and public RO are located in this region.

The Gorizia Region has surprisingly the strongest links (relative to the number of organizations) with the Central Slovenian Region. The links between the Podravska Region and in particular the Coastal-Karst Region on one side and the Central Slovenian Region on the other are quite weak, although the second and the third largest university are both in these two regions.

Evaluation of R&D *Performance by Regions*

In table 2 we present the data related to the indicators of the average R&D performance of companies, RO, and HEI in 12 Slovenian statistical regions. We took into account only the organisations included in our basic network. The table also contains data regarding the number of residents in the regions and the number of organisations in the basic network. R&D performance could be measured by three indicators

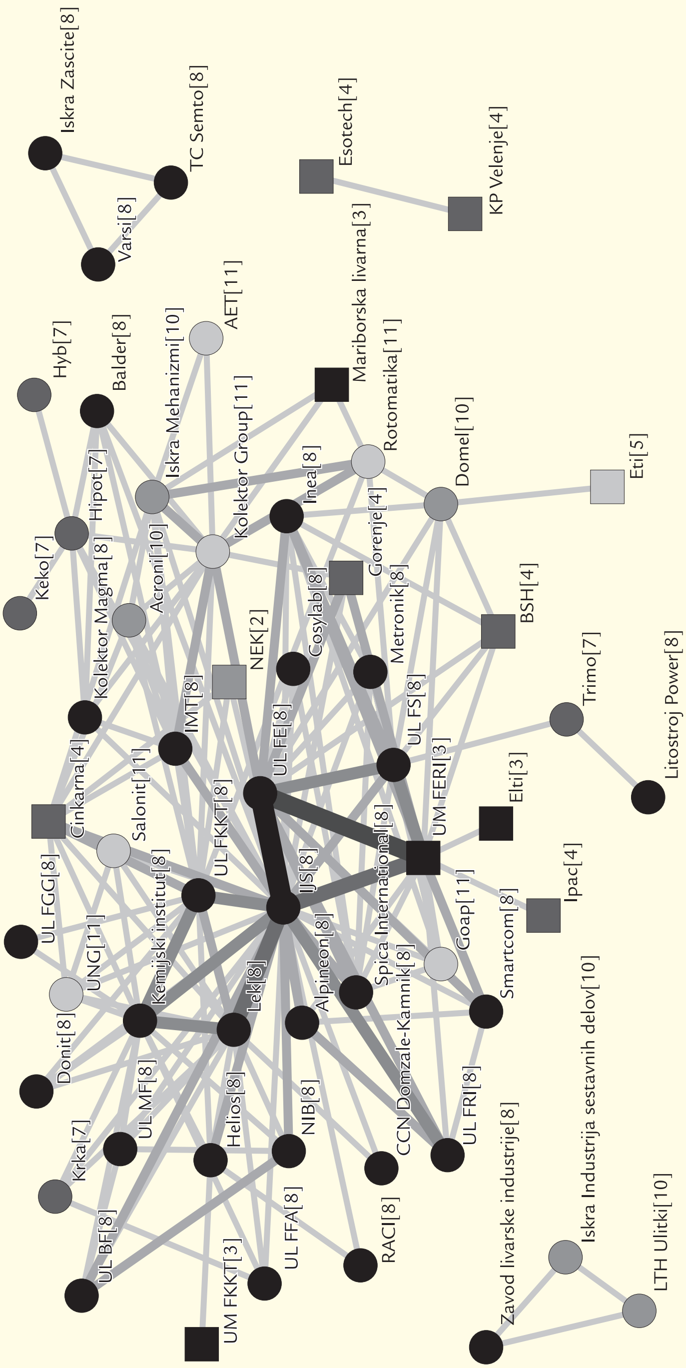


FIGURE 1 Network with edges with values of 2 or above

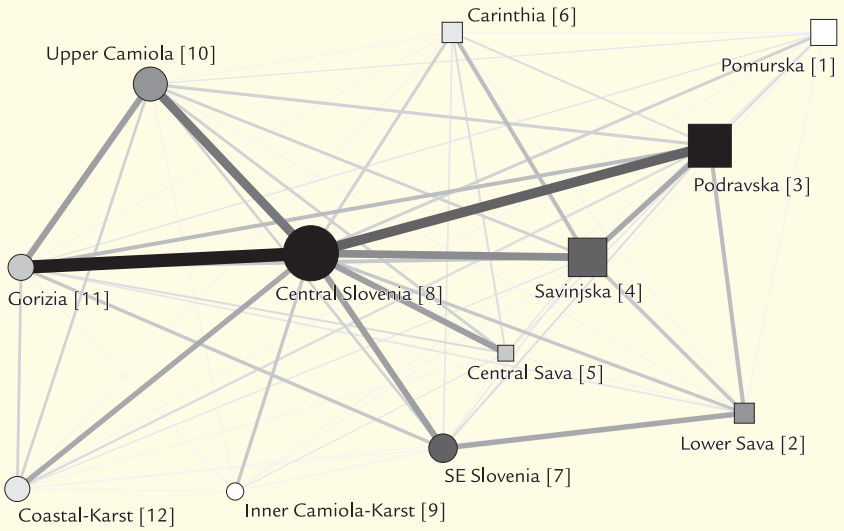


FIGURE 2 R&D network of statistical regions in Slovenia

– SICRIS points measuring publishing achievements, the number of citations measuring the relevance of research work, and the number of patents measuring commercialisation of new knowledge. We can see that the best ranking region in the sense of publishing performance is, surprisingly, the Gorizia Region, which outperforms even the Central Slovenian Region. The situation regarding the number of citations is somewhat different. The differences between the Slovenian Regions are quite big in this area, and the numbers of citations are consistent with the size of public universities in these regions (University in Ljubljana, University in Maribor, and Primorska University in the Coastal-Karst Region). The situation regarding the number of patents pinpoints the major problem of Slovenian innovation performance. The numbers are very low showing either weak commercialisation of new knowledge or its low quality. The highest numbers of patents are achieved in the Central Slovenian Region with plenty of technical and natural-science HEI and, surprisingly, in the South-East Slovenian Region with practically no HEI and RO, but with important foreign car producing company and a major Slovenian pharmaceutical company.

TABLE 1 R&D performance data in Slovenian statistical regions

(1)	(2)	(3)	(4)	(5)	(6)
Gorenjska Region	203,427	30	16.10	23.17	0.03
Gorizia Region	119,146	16	28.25	13.62	0.00
Koroška Region	72,494	15	8.53	53.53	0.00
Inner-Karst Region	52,287	8	2.00	0.00	0.00
Coastal-Karst Region	110,760	7	21.00	493.71	0.00
Central Slovenian Region	533,213	135	27.50	1877.01	0.76
Podravska Region	323,119	26	17.69	922.35	0.23
Pomurska Region	119,145	8	7.12	36.25	0.00
Savinjska Region	259,726	43	18.16	11.70	0.05
South-East Slovenia Region	142,483	21	16.57	131.14	0.48
Spodnjeposavska Region	70,167	9	2.00	0.78	0.00
Zasavska Region	44,222	13	13.00	0.29	0.07

NOTES Column headings are as follows: (1) region, (2) number of residents, (3) organisations in basic network, (4) SICRIS points per organisation, (5) citations per organisation, (6) patents per organisation.

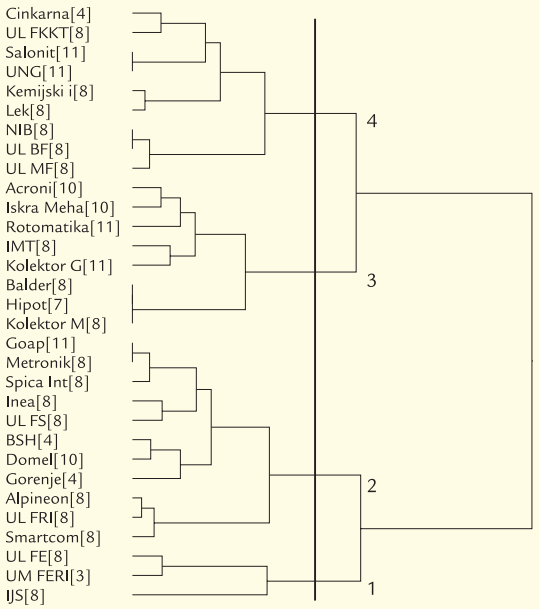
Evaluation of R&D *Performance by Internal Cohesion*

In figure 1, we can identify the organisations with most frequent co-operation. For this purpose, we used the generalized cores method. Based on the data, we found that 14 is the highest possible order in the basic network. We decided to analyse the generalized core of order 10, which means that all of the 31 organizations in the obtained core (sub) network participate in at least 10 common CC, CE, and DC, together with other organizations from this (sub) network. This is also the only (sub) group of organizations in our primary network with such a feature.

The companies in the generalized 10-core were divided into four groups using Ward's method of hierarchical clustering and generalized Euclidean distance (Ferligoj 1984; Doreian, Batagelj, and Ferligoj 2005). Dendrogram of this method of clustering is shown in figure 3. Furthermore, the core is presented with a matrix in figure 4. The organisations in the matrix are denoted by regions (with numbers in square brackets) and divided into four groups according to the outlined classification method. The matrix is symmetrical, since the net-

FIGURE 3

Dendrogram of hierarchical clustering with Ward's method

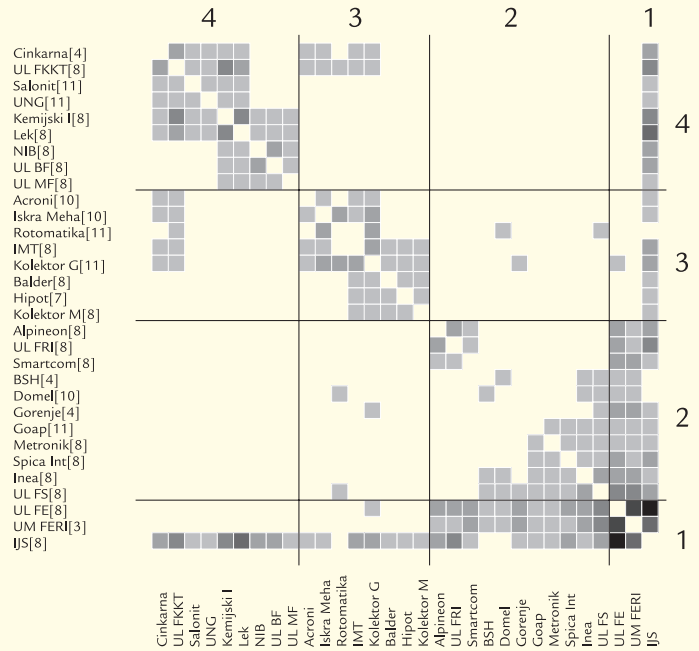


work is non-directional. The inference is that these groups might actually represent cases or rudiments of innovative networks.

As seen in figures 3 and 4, IJS occupies the central position of the Slovenian R&D cooperating with almost all organizations in the core. As we consider only the edges with weight 2 or more, 27 organizations in the generalised core cooperating with IJS participate in at least two common CC, CE or DC. There are only three exceptions: Rotomatika, BSH, and Domel.

The first, most strongly associated, group in the generalised core consists of IJS and two higher education institutions – UL FE and UM FERI, operating in the fields related to computer science, informatics, electrical engineering, and related fields. The second group consists of organizations, which are almost all involved in cooperation with the first group and some of them also among themselves. This group consists of companies whose primary activity is associated with process automation, computer engineering, and computerization, as well as development and use of electronic communications, and speech technology. Additionally, two HEI are involved in this group – the Faculty of Mechanical Engineering (UL FS) and the Faculty of

FIGURE 4
The matrix of 10-core



Computer Science and Information Science (UL FRI), which are both members of the University in Ljubljana. The third group of cooperating organizations is closely related to the development and use of electronic circuits and components, technologies, and materials for electronics with optoelectronics components and measuring instruments. The fourth group is focused on a different discipline – chemistry and pharmacy. It involves some chemical companies (Cinkarna, Salonit, Lek), two public RO (National Chemical Institute and National Institute of Biology) and relevant HEI – the University of Nova Gorica and also the Faculty of Chemistry and Chemical Technology (UL FKKT), Biotechnical Faculty (UL BF) and Medical Faculty (UL MF), which are all members of the University in Ljubljana. Some of these groups cooperate with each other poorly – typical example are groups where one focuses on research and production in the field of chemistry and pharmacy, while the other focuses on research and production in the field of automation and computerization.

In the next step, the performance of R&D for 4 recognised groups was analysed. The results are presented in table 2. The most successful

TABLE 2 R&D performance data in 4 recognised groups and IJS

Groups	SICRIS points per individual per group	Citations per individual per group	Patents per individual per group
Group 1	205.86	47.95	0.0274
Group 2	36.82	3.80	0.0015
Group 3	59.79	8.67	0.0000
Group 4	138.28	55.44	0.0330
IJS	342.86	113.55	0.0344

group regarding publishing performance is the group consisting of 2 HEI (UM FERI and UL FF) and IJS. This finding is quite logical, since IJS, when analysing its performance, is really the leading R&D organisation in Slovenia. On the other hand, the group with the best result in the area of citations is the last one – chemistry based group of companies, RO, and HEI. This group is also the best when considering the number of patents. Their achievement in this area is almost the same as the achievement of IJS. On the other hand, R&D performance of group 3 and also group 2 is rather poor (despite the fact that IJS is also involved in these two groups). In group 3, for example, there has been no evidence of registered patents, which is quite worrying since there are some leading Slovenian companies (e. g. Gorenje) in this group.

DISCUSSION AND IMPLICATIONS

With the study we attempted to identify innovative clusters in Slovenia. As a base for the research, we analysed three governmental mechanisms for the encouragement of R&D activities through cooperation between business sector (companies), public RO, and HEI, which represent quite a big share of public spending for R&D in Slovenia. These three mechanisms are: competence centres, centres for excellence, and development centres.

Through the analysis, we confirmed the basic assumptions stemming from the theory of networking. We found that innovative clusters (or groups as we defined them) usually consist of members, which come from similar disciplines or industries (in our case process automation, computer engineering, computerization, development and

use of electronic components, chemistry etc.), that there should be some history of cooperation present in the group (there are obvious relationships between HEI, which educate engineers and RO or companies where these engineers mostly operate), and that groups
[78] are usually geographically concentrated (we even recognised relatively weak cooperation between different Slovenian statistical regions). Additionally, we confirmed and revealed some of the problems related to Slovenian technological development and consequent economic performance. We also identified weak links between research performance (SICRIS points), relevance of research (number of citations) and transfer of knowledge (number of registered patents). The main weakness of the Slovenian R&D space seems to be relatively weak cooperation between business, HE, and research combined with the dominance of a single public research organisation. It seems that synergies, which are probably expected due to the introduction of three networking mechanisms, are actually not implemented.

This study represents one of the first attempts to analyse the cooperation and clustering issues in R&D in Slovenia. Our findings and approaches to the study could be a starting point for further research. We are sure that such research could bring benefits to both – theory and practice. Although Slovenia is a Mediterranean country, it is, by its cultural values and practices, a part of the Eastern European cultural cluster (Bakacsi et al. 2002). Societal culture has strong association with national rates of innovation. Shane (1993) found that national rates of innovation are most closely associated with the cultural value of uncertainty acceptance, and that the lack of power distance and individualism are also related to high rates of innovation. Cultural values of citizens and their assimilated behavioural patterns are important determinants of the acceptable rate of cooperation and interaction between the members of society, the attitudes toward hierarchy, and the tolerance of unclear future (Babnik 2010). These are important elements of the innovation process (Hidalgo and Albors 2008) and the process of inter- and intra-organisational cooperation, and are present in the Slovenian culture (Babnik 2010). Further research in this field should therefore take into account the cultural features of the society and the network in which the innovation process is performed.

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