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INTER-ORGANIZATIONAL LINKAGES OF SCIENCE. THE CASE FROM POLAND

Summary. The purpose of the paper was to characterize the network structure of science-industry cooperation in Poland. Social network analysis (SNA) was applied for graphics and calculation. Network construction was based on POL-on „scientific projects" database supporting Polish governmental organizations. The analysis was focused on scientific entities and was conducted from inter-organizational and inter-regional perspective.
Keywords: science, inter-organizational relations, SNA, innovation

RELACJE MIĘDZYORGANIZACYJNE ŚWIATA NAUKI. PRZYPADEK POLSKI

Streszczenie. Niniejszy artykuł stanowi opis struktury sieciowej współpracy naukowo-przemysłowej w Polsce. Dla celów opracowania graficznego zagadnienia oraz dokonania podstawowych obliczeń zastosowano metodę analizy sieci społecznych (*social network analysis – SNA*). Prezentowaną sieć zidentyfikowano na podstawie bazy „projekty naukowe" systemu POL-on. Analiza koncentruje się na podmiotach naukowych i obejmuje zarówno perspektywę międzyorganizacyjną, jak i międzyregionalną.
Słowa kluczowe: nauka, relacje międzyorganizacyjne, analiza sieci społecznych (SNA), innowacje

1. Introduction

The world today is linked as never before. The development of communication technologies, globalization and internationalization processes force contemporary economic entities to conduct their activities within a wide network of inter-organizational linkages. Despite its traditional research and education function, science, which, plays a vital role in

transforming knowledge into real market value, needs to create relationships with other innovation actors. Science-industry cooperation through developmental works or joint research projects facilitates better transfer of tangible technical results or intangible technical knowledge to practice. These days, universities and scientific institutes appear to actively search for new partners for research and utilitarian projects. This is consistent with triple helix model (Etzkovitz, Leydesdorff, 2000) which assumes the mutual stimulation for economic development based on compound relations between science, business and governmental institutions.

The concept has been well adopted at regional level and thus has become the essence of regional innovation systems. Those developed networks of cooperating institutions and companies are to provide efficient knowledge distribution, knowledge transformation into innovations as well as knowledge creation. The demand for enhancing the inter-organizational cooperation has inspired many European and governmental programmes focused on building linkages between various entities. In recent years, the governments in Poland (both at local and national level) have also been making efforts to stimulate those relations. This usually takes the form of supporting funds and promotion.

The above context generated the scientific interest in relations within innovation systems, with a special role of the scientific sector (see: Mora-Valentin, Montoro-Sanchez, Guerras-Martina, 2004; Bercovitz, Feldman, 2007; Huggins, Izushi, Prokop, 2010). Also, this paper is focused on the assessment of Polish universities and R&D institutes' ability to participate in inter-organizational scientific projects, including the territorial aspect of the analysis.

2. Method and dataset

The conducted analysis is focused on linkages structures and was conducted with the use of social network analysis (SNA). SNA is a method used for graphics and calculation for compound, large and multilevel structures of relations between objects (Wassermann, Faust, 2007). It applies to linkages between social entities (such as persons, teams, organizations, regions, etc.) and its main structure is the network presented as graphs. SNA has been widely used for structural analysis of emerging networks and their connection with the level of innovativeness in structures such as clusters (Østergaard, 2007), regional innovation networks (Fritsch and Kauffeld-Monz, 2010) or even inter-organizational research teams (Kijkuit and van den Ende, 2010). Moreover, it is an effective tool to be used in scientific performance evaluation, such as paper co-authorship (Newman, 2004) or shared patent applications (Xu, 2010).

The graphs consist of vertices (nodes) and connections between them (edges). Creation of such a structure requires identification of the entities that are included in the structure (the network's delimitation) and recognition of the relations that were established. The results presented in this paper are based on POL-on (https://polon.nauka.gov.pl/) – an integrated database with information about higher education in Poland. The system is to support works of Ministry of Science and Higher Education, Central Statistical Office of Poland and Degrees and Titles Committee. However, only part of data is publicly available[1].

For the purpose of this research procedure, data were collected on 15th December 2014 from "scientific projects" database and included all projects which started in 2011 and which were conducted by at least two separate partners (separate faculties from the same university were treated as one partner), or more. There were identified 15 inter-organizational projects with the participation of at least one Polish scientific entity (see: tab. 1).

Table 1

Scientific projects included in POL-on starting in 2011 by the number of participants

Number of participants	**2**	**3**	**4**	**5**	**7**	**9**	**12**	**21**	
Number of projects	**4**	**3**	**2**	**1**	**2**	**1**	**1**	**1**	*Total* **15**

Source: Own study based on POL-on (https://polon.nauka.gov.pl, 15.12.2014).

In total, there were identified 73 entities that were partners within recognized projects (tab. 2), most of which were scientific institutions such as universities, R&D institutes or university hospitals (over 67%). However, in those initiatives nearly 25% participants were the industry representatives. Moreover, there were also three cases of governmental institutions' activity, namely of a city council, regional authorities as well as administrative and management structure that integrates public hospitals and public health service. Other types of identified vertices were a teacher training centre, a cooperative performing in casting industry, and an international educational association.

[1] Polish public scientific institutions are obliged by the Minister of Science and Higher Education to use the system in order to report their activity. However, the reporting system is currently in the transitional period and thus the database may be incomplete.

Table 2

Partners in scientific projects included in POL-on (2011) by their type

Region/Country	Science	Industry	Government	Other	*Total*
Lower Silesian	1	2	0	0	3
Kuyavian Pomeranian	0	0	0	0	0
Lublin	1	0	0	0	1
Lubusz	0	0	0	0	0
Łódź	1	2	0	0	3
Lesser Poland	2	0	0	0	2
Masovian	9	3	0	1	13
Opole	0	0	0	0	0
Subcarpathian	0	1	0	0	1
Podlaskie	1	0	0	0	1
Pomeranian	2	3	0	0	5
Silesian	4	4	1	1	10
Świetokrzyskie	0	0	0	0	0
Warmian-Masurian	0	0	0	0	0
Greater Poland	2	0	0	0	2
West Pomeranian	1	0	0	0	1
Belgium	2	1	0	0	3
Czech Republic	1	0	0	0	1
Denmark	0	0	1	0	1
Finland	2	0	0	0	2
France	2	0	0	0	2
Germany	5	1	0	0	6
Greece	1	0	0	0	1
Hungary	0	0	0	1	1
Italy	2	0	0	0	2
Mexico	1	0	0	0	1
Norway	1	0	0	0	1
Spain	2	0	1	0	3
Ukraine	1	0	0	0	1
United Kingdom	5	1	0	0	6
Total	49	18	3	3	73

Source: Own study based on POL-on (https://polon.nauka.gov.pl, 15.12.2014).

9 of 15 analyzed projects were of interregional character (i.e. there were participants from different regions of Poland). There were also recognized three international initiatives (which linked entities from 15 countries in total). Three other ventures were of intraregional character but in each case it was cooperation between only two partners.

The comparison of scientific sector's activity in Polish regions reveals the dominant character of Masovian Voivodeship (it is not surprising as it is a central region where many headquarters and governmental institutions are located). However, taking other types of institutions into consideration, the position of Silesian region is also significant in the identified network. However, research institutions from 5 Polish regions did not launch the scientific project in 2011.

The edges of the recognized structure were defined as equal and mutual. The assumption of linkage equality determines the construction of undirected graph as there were not indicated the source and receiver of relations. On the other hand, the mutuality of connections means that each project partner is linked with other partners as well. There were also applied multiple edges (if the same partners participated in more than one scientific project). There were identified 389 relations in total (tab. 3) including 3 cases of tripled relations (between three scientific institutions from Lesser Silesian and Silesian region: AGH University of Science and Technology, Strata Mechanics Research Institute of the Polish Academy of Sciences and Central Mining Institute). Also, doubled relations were identified among the aforementioned organizations as well as two large mining companies located in Silesia.

Table 3

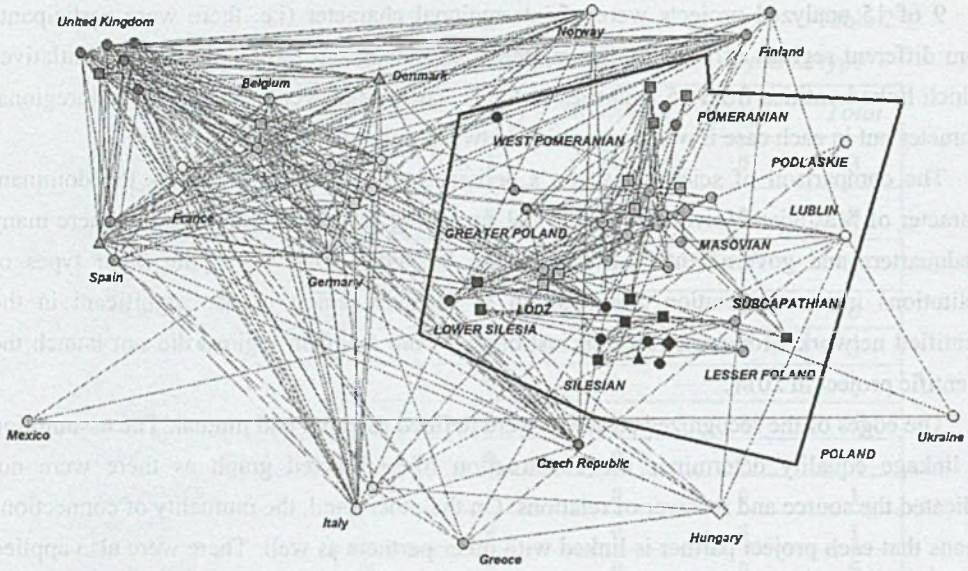
Multiple relations in identified network

Type of relation	Number of lines	Lines in Total
Single	**364**	**364**
Doubled	**8**	**16**
Tripled	**3**	**9**
		Total **389**

Source: Own study based on POL-on (https://polon.nauka.gov.pl, 15.12.2014).

3. Network representation

The above recognition allowed for construction of the network representation provided below (Fig. 1). For graphics and calculation there was applied software Pajek 2.04 (Batagelj, Mrvar, 1998). The geometric figures of nodes represent different types of organization (triple helix sphere). The colours symbolize the territorial attributes (region or country).



** Symbols: ellipse – science, box – industry, triangle – government, diamond – other*

Fig. 1. Basic network of scientific projects based on POL-on (year 2011)
Rys. 1. Sieć podstawowa projektów naukowych na podstawie bazy POL-on (2011 rok)
Source: Own study with the use of Pajek 2.04.

The graphics presented above may appear slightly ambiguous as quite a high number of project participants (up to 21 entities) create the structure of large density (as over 14% of possible linkages occurred in the network). However, as the analysis is conducted from Polish perspective, this quantity is not informative (as there is no information about existing linkages between the indicated foreign organizations).

In order to better understand the structural cohesion of the research projects run with participation of Polish science, there were identified some components. A component is a separate subgraph that includes vertices linked directly or indirectly i.e. there is a direct or indirect connection between each two nodes from this group (De Nooy et al., 2005). The calculations conducted with Pajek 2.04 enabled to identify 9 components. The largest one consists of 21 entities involved in a project on medical sciences and from Poland there is the only one separate participant – Medical University of Silesia. On the other hand, there also is the component which consists of 20 organizations (over 27% of the whole network) with links between Polish military universities (e.g. Military University of Technology, Polish Naval Academy), military R&D institutes (Military Institute of Armament Technology, Military Institute of Chemistry and Radiometry) and military companies (AMZ Kutno), as well as civil universities of technology (Warsaw University of Technology) and private

enterprises. However, there also exist four isolated components in the structure which include a single link between two organizations. In three cases those relations are of intraregional character.

If the network is multilevel and compound (e.g. because of the large number of relations), it is possible to shrink it with the inclusion of discreet attributes of vertices (as its geographical localization). This allows for better representation of the interregional linkages (Fig. 2).

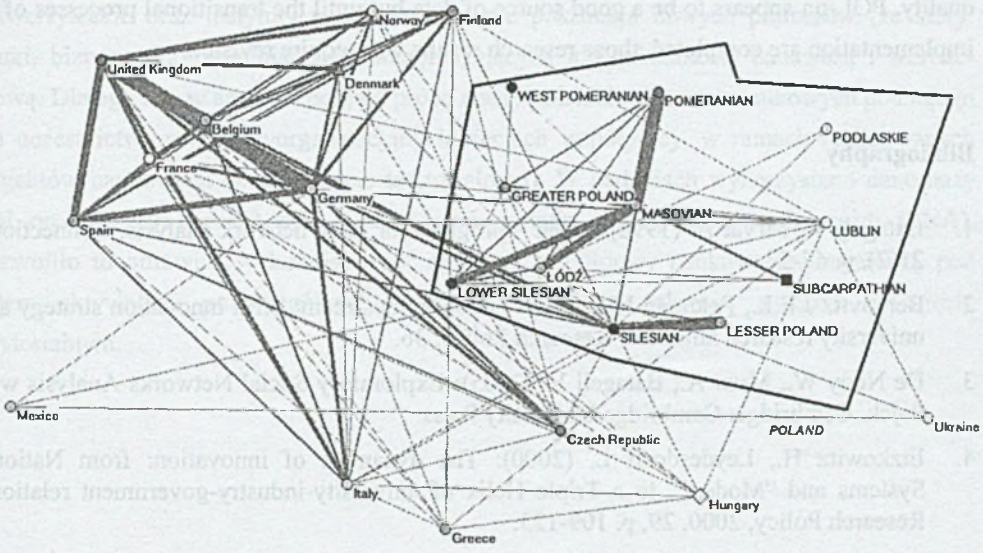


Fig. 2. Network of scientific projects based on POL-on (year 2011) shrunk by localization
Rys. 2. Sieć projektów naukowych na podstawie bazy POL-on (2011 rok) zredukowana według lokalizacji
Source: Own study with the use of Pajek 2.04.

The graphics of shrunk network enables identification of strong scientific relations that are established between Pomeranian and Masovian region, Lesser Poland and Silesian region as well as between Masovian and Lower Silesian Voivodeship or Masovian and Łódź province. Moreover, the internationalization of research activity is most visible in Silesian region.

There was calculated a degree centrality for each vertex of the shrunk network as the number of relations with adjacent nodes. The rank of regions (excluding the foreign countries) revealed that Silesian region is a leader as it is linked with 16 other regions or countries (including 6 Polish regions and 10 foreign countries). The following ones are Lublin (connections with 10 foreign countries but none with domestic region) and Masovian Voivodeships (relations with 7 Polish regions without participation in international projects).

4. Conclusions

The conducted research analysis reveals the structure of emerging research network in Europe from the Polish perspective. SNA may help in the assessment of cooperative efforts of scientific institutions as it provides quantitative information about the potential of particular innovation players. Moreover, it provides valuable information about territorial context of the identified linkages. However, the credibility of such research is still dependant on dataset quality. POL-on appears to be a good source of data but until the transitional processes of its implementation are completed, those research results will require revision.

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Omówienie

Współczesne podmioty gospodarki, w tym również instytucje sektora nauki, prowadzą swoje działania w ramach szerokich, międzyorganizacyjnych powiązań. Ośrodki uniwersyteckie oraz instytuty naukowe aktywnie poszukują nowych partnerów (ze sfery: nauki, biznesu oraz administracji), wspomagających ich działalności badawczą i wdrożeniową. Dlatego też, w artykule podjęto próbę oceny polskich jednostek naukowych pod kątem ich uczestnictwa w międzyorganizacyjnych sieciach współpracy, w ramach realizowanych projektów naukowych (w kontekście terytorialnym). W badaniach wykorzystano dane bazy POL-on (dla 2011 roku) oraz zastosowano metodę analizy sieci społecznych (SNA). Pozwoliło to omówić „wyłaniającą się" strukturę współpracy naukowo-przemysłowej pod kątem aktywności poszczególnych podmiotów w tym zakresie, a także w ujęciu terytorialnym.