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# INTERNATIONAL COLLABORATION OF POLISH RESEARCH ENTITIES IN A TERRITORIAL CONTEXT

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**Abstract:** The aim of the article was to characterize the structure of scientific collaboration launched by Polish institutions in partnership with foreign entities in 2019 with a special focus on the territorial context. An analysis of the network generated on the basis of data from the POL-on system was made: weak components, the degree centrality and the betweenness centrality for each entity were identified, as well as significant connections in the network reduced to the level of countries and to voivodeships. A key entity in the network was indicated (the Central Mining Institute). Some foreign entities show high betweenness centrality in the considered network. At the level of relations between countries, the high network density and significant activity of institutions from Germany were observed, which in the future may hinder gaining advantages. Scientific collaboration of Polish institutions is carried out mainly with centres located in Europe, but it is generally not cross-border.

**Keywords:** collaboration, scientometrics, SNA.

## 1. Introduction

The globalization of the modern world is a fact and is associated not only with the integration of national economies, multidirectional migration of people, flow of capital and resources, but also with the intensive exchange of knowledge. The need to consider scientific problems in a global context is becoming a necessity, and the internationalization of research is becoming a desirable phenomenon at various levels.

At the individual level, some scientists, thanks to available ICT tools, lower travel costs and the universalization of the language of science (English dominates in most fields), are currently seeking to attract foreign partners, and furthermore to increase their international visibility. Scientific institutions are also focused on international cooperation, which has been proven to result in the greater productivity of scientists (Abramo, D'Angelo, and Di Costa, 2009), which in turn ensures a better position in prestigious rankings. In addition, a partner at this level is sought to exploit harnessing differences, among others, in terms of knowledge, skills, equipment, resources, but also financing (Bammer, 2008). Scientists cooperating on the international arena (and thus competing globally) are employed by competing scientific institutions, which in turn translates into the development of cities and regions in which they are located (Olechnicka, Płoszaj, and Celińska-Janowicz, 2019). At the national level, on the other hand, efforts are made to identify and solve global social problems, for which an international research perspective is useful (Woldegiyorgis, Proctor, and de Wit, 2018). In addition, for several years in Poland it has been postulated to reorient universities towards research and implementation activities (with less focus on teaching activities), which would be accelerated thanks to their internationalization. There are also opinions that including Polish centres in multinational research networks could support state policy even in such areas as diplomacy (Hofman, 2015). The issue of internationalization of science is therefore important for many different stakeholders and is a matter of state importance, since the lack of links with the global research network threatens marginalization.

Hence, in this article an attempt was made to describe the international cooperation of Polish science at meso level (identified from the perspective of scientific institutions in the context of their localization in regions and countries), by seeking answers to the following questions:

- Is the international collaboration of Polish science polarized:
  - at the level of the institution (organizational units) – are there specific centres that are more capable than others to establish this cooperation?
  - at the level of regions (voivodeships) – are these centres geographically concentrated in specific regions of Poland? Is there intensive cross-border cooperation?
  - at the national level – is the collaboration concentrated in several partner countries or is it distributed?

## 2. Research methodology

Many studies on research collaboration (and its internationalization) were carried out using the co-authorship of publications of individual scientists and their affiliations (see, e.g. Kwiek, 2020). This data is also used to describe the spatial extent of such collaboration (Waltman, Tijssen, and van Eck, 2011). Bibliometric analyses become the basis for assessments of scientific research conducted by institutions and the

agencies financing them (Hicks, Coil, Stahmer, and Eisen, 2019). However, it should not be forgotten that the co-authorship of scientific papers, despite its huge popularity, as a measure of research collaboration has its limitations (e.g. a single author may be affiliated in several places and thus it may generate data on the institution's cooperation artificially) (Katz and Martin, 1997).

The need for a more comprehensive approach to measuring the internationalization of research in universities was postulated by Woldegiyorgis, Proctor, and de Wit (2018). Similarly, Wazenböck, Scherngell and Brenner (2014), when considering the exchange of knowledge at interregional level, proposed the extension of applied analyses and, in addition to the network of joint publications, they also included a network of co-patents and a network of co-participation in scientific and research projects (in this case financed from the Framework Programs). The last of the measurement methods they proposed was used in the research presented in this paper.

The subject of the presented study is the international research and development collaboration of Polish scientific institutions (including their location in regions), which was mapped in the form of a network (graph). The network participants were identified on the basis of data contained in the 'scientific projects' database of the POL-on system (in the form of a publicly available dataset) – the integrated system of information on science and higher education (the central nationwide ICT system in Poland)<sup>1</sup>. This is a tool supporting decision-making processes primarily on the part of the Ministry of Science and Higher Education, as well as other government agencies. The use of the native database was aimed at analysing a relatively comprehensive<sup>2</sup> list of scientific projects financed from various sources (including national sources) and organized within various programs<sup>3</sup>. The collected data made it possible to identify the activity of individual organizational units in the studied area (e.g. individual faculties in the case of universities), which allows for differences typical for different disciplines to be taken into account.

On 13 April 2020<sup>4</sup>, a list of all scientific projects was downloaded, the implementation of which began in the period from 1 January 2019 to 31 December 2019. A total of 3313 projects were identified, of which 205 were implemented with

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<sup>1</sup> Currently, work is underway on the development of the POL-on system and two versions are available (POL-on and POL-on 2.0), while the first version was used in the study. It is available at: [polon.nauka.gov.pl](http://polon.nauka.gov.pl).

<sup>2</sup> POL-on is a reporting system of Polish scientific units, which means that all the scientific units located in Poland are required to insert information on their activities in the database (see the legal acts: Ustawa z dnia 30 kwietnia 2010; Rozporządzenie z dnia 29 czerwca 2015).

<sup>3</sup> One should keep in mind several limitations of the POL-on system. Firstly, the database does not include projects covered by the protection of classified information regarding defence and the security of the state, and projects implemented in cooperation with companies that have reserved the confidentiality of the enterprise. Secondly, the reliability of the study depends on the quality of the data inserted to the system.

<sup>4</sup> In accordance with the act Ustawa z dnia 3 lipca 2018 (art. 219 par. 6), entities obliged to insert data to the POL-on system for 2019 had to do this by March 31, 2020.

the cooperation of at least two different scientific units, while 41 projects which were implemented with the participation of at least one organization located abroad, were further analysed.

The research used the Social Network Analysis (SNA) method, which uses graph theory for visual presentation and quantitative characteristics of interrelations (edges) of various objects (vertices, nodes) (see Batorski and Zdziarski, 2009), with the Pajek 64 5.08 program.

### **3. International scientific collaboration from the perspective of scientific units**

#### **3.1. Bimodal network (of projects and participants)**

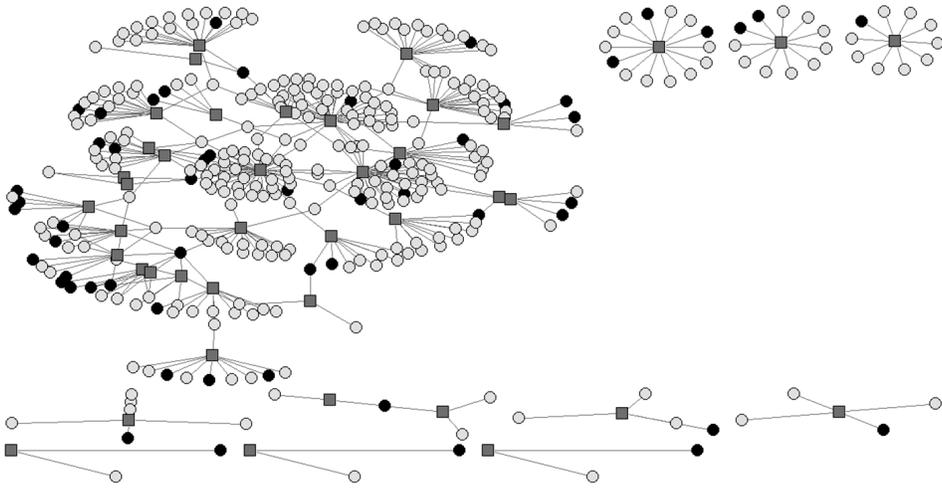
In 2019 the implementation of 41 scientific projects began in Poland, based on international cooperation. In total, 344 entities took part in all these projects, of which 55 (nearly 16%) were Polish organizations (including 43 scientific units, 7 enterprises and 5 organizations of a different type). Figure 1 presents a bimodal network of these connections (i.e. a network that includes nodes belonging to two separate categories). Some Polish scientific institutions participated in very large projects – 19 of all the recognized international projects are implemented by not less than ten organizations (the largest of which involves as many as 44 entities). Small projects, involving the cooperation of only two or three entities, make up nearly a quarter of the launched projects.

The network distinguishes eleven connected components, which are a set of graph vertices (subgraph), within which there exist direct or indirect connections between all pairs of vertices (De Nooy, Mrvar, and Batagelj, 2005). In nine cases these components are isolated and cover individual projects, which means that all organizations implementing these projects in 2019 participated only in cases of international scientific collaboration<sup>5</sup>. One small component was also observed. It covers two separate projects that are implemented simultaneously by the Intercollegiate Faculty of Biotechnology of the University of Gdansk and the Medical University of Gdansk (one project in cooperation with two scientific institutions from Shanghai and the other in cooperation with a Chinese university).

One large component was distinguished, covering over 81% of the area of the identified network. It includes 30 projects implemented with the participation of Polish scientific institutions, in which individual participants also cooperate in other identified projects. To recognize participants involved simultaneously in

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<sup>5</sup> The analysis is conducted from a Polish perspective and includes only international projects implemented with Polish participation. In fact, the components presented here as isolated can be related to other projects through foreign organizations that also carry out other international research or development projects, but without the participation of Polish scientific institutions.



Key: squares – projects, circles – organizations implementing the project, black – organizations located in Poland.

**Fig. 1.** Bimodal network of participation in international scientific projects implemented with the participation of Polish scientific units launched in 2019

Source: own work based on POL-on data (2020), with the use of Pajek64 5.08.

**Table 1.** Organizations participating in at least three international scientific projects implemented in cooperation with Polish scientific units launched in 2019

Organization name*	Number of projects
<b>Central Mining Institute (Poland)</b>	7
Centre for Research and Technology Hellas (Greece)	4
<b>Jerzy Haber Institute of Catalysis and Surface Chemistry Polish Academy of Sciences (Poland), The Henryk Niewodniczański Institute of Nuclear Physics Polish Academy of Sciences (Poland), Aarhus University (Denmark), Brown Coal Research Institute, Inc. (Czech Republic), Katholieke Universiteit Leuven (Belgium), The French National Centre for Scientific Research (France), Technical University of Denmark (Denmark), University of Aveiro (Portugal), University of Nottingham (United Kingdom), University of Oslo (Norway), University of Oviedo (Spain), Universitat Politècnica de València (Spain)</b>	3

\* The table marks entities located in Poland in bold.

Source: own work based on (POL-on, 2020).

several initiatives, the degree centrality<sup>6</sup> was calculated for scientific units in the bimodal network under consideration. On this basis, Table 1 shows the entities that in 2019 were involved in at least three different scientific projects implemented in international cooperation with at least one Polish research unit.

Only three Polish research units participated in at least three different projects in the analysed network, with the Central Mining Institute launching as many as seven projects in 2019. Interestingly, as many as eleven such foreign entities were identified in the network. The efforts of Polish entities seem to be rather focused on individual initiatives. There is also a noticeable tendency rather to engage forces in large projects (with a large number of participants).

### 3.2. Unimodal network (connections between participants)

The bimodal network was transformed into a unimodal network of organizations connected by participation in the same project in such a way that the noted connections are reciprocal and each project participant is connected to every other participant in the same project<sup>7</sup>. In this network, a total of 3590 connections of 344 entities were recorded, of which 47 are multiple relations (when two scientific units participate together in the implementation of several different projects). At this stage, the betweenness centrality was calculated for each of the vertices, denoting the ratio of the shortest paths between pairs of other nodes that contain this vertex. This allows to identify critical vertices which have potentially the most control over flows in the network. In the presented case, the highest value is again shown by the Central Mining Institute, which thanks to participation in as many as seven different projects (medium-sized – from 6 to 17 participants) has access to different areas of the network (it is directly linked to 49 other entities), while it undertook cooperation with the University of Oviedo and the Centre for Research and Technology Hellas three times. In addition, this entity participated in international projects together with nine national organizations. Another Polish organization that achieves high betweenness centrality value is the Jerzy Haber Institute of Catalysis and Surface Chemistry Polish Academy of Sciences, but this is only placed sixteenth in the ranking. It turns out that foreign institutions participating in several large multinational projects are strong intermediaries in the network in question.

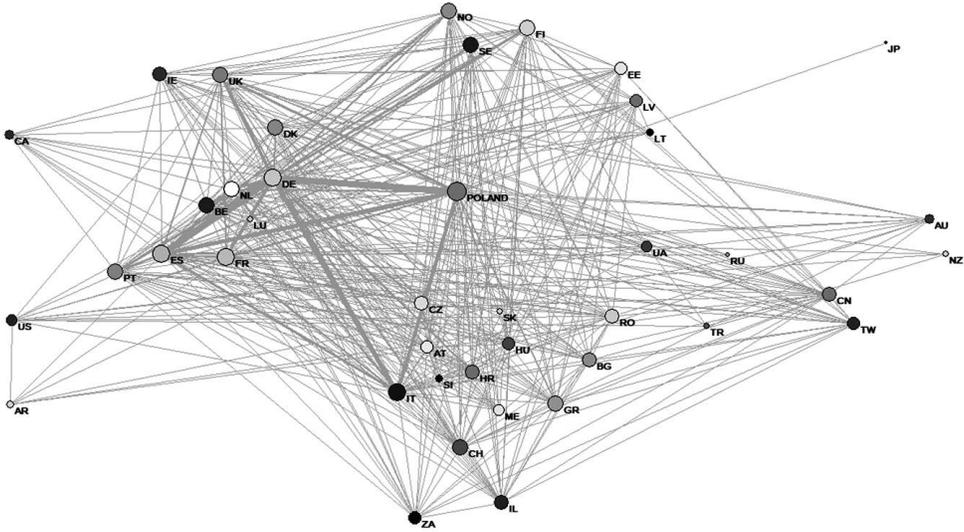
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<sup>6</sup> The degree of the vertex means the number of connections of a given vertex with others. In the case of the bimodal network in question, there are the only connections between the project and its participants, hence the degree of the vertex for the project means the number of its participants and for the organization means the number of projects in which it participates.

<sup>7</sup> In this work the existence of relationships between entities was identified on the basis of formal participation in a joint research or development project. However, not all organizations involved in the project need to build direct relationships with each other (this is particularly difficult in large research consortia). Moreover, as part of a given undertaking, some entities may create local cliques at the expense of collaboration with other participants (Czakov, 2012, p. 73).

#### 4. International scientific collaboration from a national perspective

The network was reduced to the relations recorded between countries (remembering that the data determine the egocentric perspective of Polish scientific entities), while the intensity of these connections (understood as the number of relations of the entity's co-participation in a given country in a scientific project with another organization from a given country) is reflected by the thickness of the edges in Figure 2.



**Fig. 2.** Network of participation in international scientific projects (implemented in cooperation with Polish scientific units launched in 2019), reduced to the level of countries

Source: own work based on POL-on data (2020), with the use of Pajek64 5.08.

In 2019, Polish scientific units began cooperation with entities from 41 other countries. Basically, collaboration usually includes European organizations. The transcontinental collaboration mostly concerns China.

In the entire network, 427 international connections were noted, including as many as 321 repetitive relations between two countries. After removing the loops, meaning domestic relations (resulting from the participation of several entities from the same country in one project), the density for the presented reduced network was calculated, which was about 0.5. This means that nearly half of the possible connections occurred in the network. Such high coherence of the network indicates not only numerous research and development collaboration relations between Poland and other countries, but also strong mutual cooperation between other project participants (especially from European Community countries). In such a network,

Poland's position as an important node controlling knowledge flows is at risk, even despite the fact of dealing with an egocentric network (there were omitted projects that were implemented between other countries without Poland's participation).

One can observe numerous relations between other European countries and Germany's dominance in this respect (see Table 2), which recorded the second highest result for betweenness centrality in the network.

**Table 2.** Ranking (seven first items) of the number of international cooperation links in scientific projects implemented with the participation of Polish scientific units launched in 2019

Ranking position	Countries	Number of connections
1	Poland – Germany / Germany – Spain	122
2	Germany – Italy	90
3	Poland – Spain	76
4	Germany – United Kingdom	64
5	Poland – Italy / Germany – France	56
6	Germany – Netherlands	48
7	Poland – United Kingdom	46

Source: own work based on (POL-on, 2020).

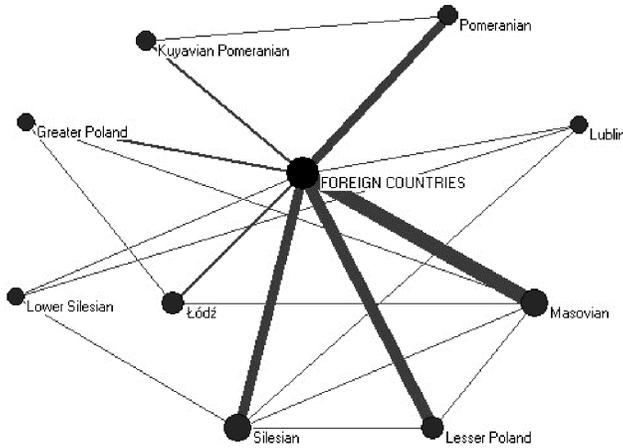
Poland carried out joint undertakings most often in cooperation with German, Spanish, Italian and UK organizations. In addition, the research and development collaboration is implemented with all neighbouring countries, except for Belarus.

## 5. International scientific collaboration from a regional perspective

In 2019, units located in nine voivodeships<sup>8</sup> began international scientific cooperation (see Figure 3).

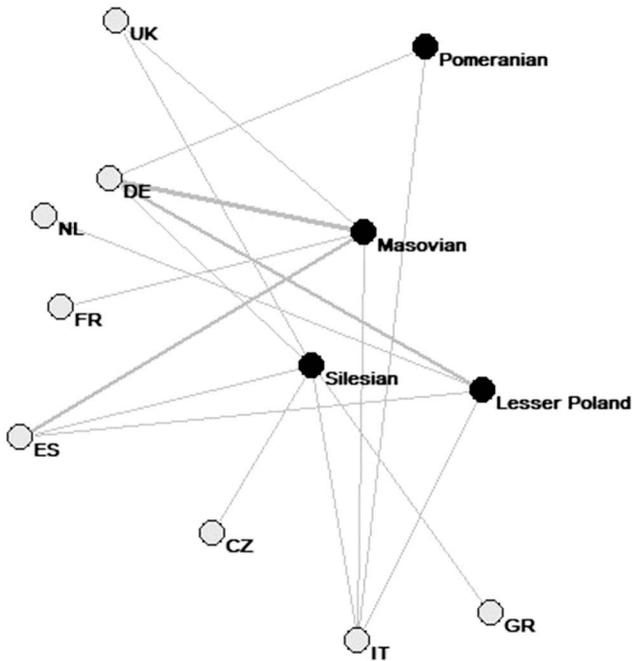
By calculating the top ranking for individual Polish regions, it was possible to indicate voivodeships in which the discussed collaboration is implemented most widely (with the largest number of countries or other regions of Poland) under the identified international projects. Thus the largest range can be observed in the Masovian region (36 links), followed by the Pomeranian and Lesser Poland voivodeships (33 links each). Intra-national and even intra-regional collaborations are also noticeable. For example, units located in the Silesian voivodeship in as many as 13 cases jointly participated in international scientific projects.

<sup>8</sup> In 2019, entities from the Lubusz, Opole, Subcarpathian, Podlaskie, Swietokrzyskie, Warmian-Masurian and West Pomeranian voivodeships did not participate in the international cooperation projects.



**Fig. 3.** Participation network in international scientific projects (implemented in cooperation with Polish scientific units launched in 2019) – perspective of Polish regions

Source: own work based on POL-on data (2020), with the use of Pajek64 5.08.



**Fig. 4.** The context network of co-participation in international scientific projects (implemented in cooperation with Polish scientific units, launched in 2019) – the strongest relations (more than ten cases of cooperation)

Source: own work based on POL-on data (2020), with the use of Pajek64 5.08.

Taking into account the cooperation that is implemented between regions and representatives of individual countries, the network was limited to taking into account the strongest relations (covering more than ten cases of such cooperation in 2019) (see: Figure 4).

Only four Polish voivodeships have strong links within international scientific cooperation. The most numerous connections were noted between the Masovian or Lesser Poland voivodeships and German organizations as well as the Masovian voivodeship and Spain. Strong cross-border connections were observed only between the Silesian voivodeship and entities located in the Czech Republic.

## 6. Conclusion

Polish scientific institutions participate in international research and development initiatives (although in 2019 they accounted for just over 1% of all scientific projects launched), and often these are projects implemented in large consortia. Most of the institutions that started international scientific collaboration in 2019 participated in a single project, with several exceptions observed in this regard. The Central Mining Institute dominates in this respect in the identified network and has the ability to cooperate under various initiatives (financed from various sources). This allows it to become a key intermediary in the analysed network – an entity that, in addition to the possibility of gaining benefits (e.g. knowledge) from many dispersed sources, can potentially regulate the flow of these benefits between participants of various projects in which it participates. It is interesting that there are more intermediaries in the recognized network, and many are located outside of Poland. It turns out that Polish entities taking part in individual multinational research initiatives prevent their exclusion from world science, but they also do not gain significant advantages in it.

In the European Union at national level, even from the perspective of the presented egocentric network, one can observe intensive research and development cooperation processes between its various members (countries). Yet in the long run, the benefits of broad collaboration may decrease – too much network density is associated with the fact that its members will have similar access to the same resources, and in this situation it is difficult to gain advantages (e.g. in the form of unique knowledge). Moreover, maintaining such multilateral relations brings costs.

Polish units implement scientific projects mainly with partners located in Europe (examples of transcontinental cooperation are rather marginal cases). Undoubtedly, the conditions for receiving external research funding have an impact on this state of affairs. The most intensive cooperation is observed with German organizations. However, this cooperation does not seem to have a strong cross-border character, as organizations located in this country also form numerous relations with countries with which they do not border directly. The collaboration of Polish representatives with neighbouring countries is implemented, but more individually and does not constitute the main direction of Polish science (all the more so that no entities from as many as six border voivodeships were involved in international projects launched

in 2019). The only place where the cross-border nature of cooperation can be slightly more noticeable is the Silesian-Czech border.

The potential of individual regions to undertake international cooperation is not clearly polarized. Although as many as seven out of sixteen voivodeships were not recorded in the network in question, and only four were more active, no visible dominance of any of them was observed. In this case, it is impossible to identify factors that would affect the location of research and development organizations particularly directed towards international cooperation or the conditions favourable towards the implementation of such projects in individual regions.

The considerations presented in this paper are based on an affiliate network in the form of partnerships in joint projects. This means that the actual involvement of individual entities in collaboration at various stages of project implementation has not been taken into account here (not all partners in fact need to be fully involved in joint activities throughout the duration of the project) and no measurable results of cooperation have been referred to (in the form of joint publications or patents). This constitutes a different research perspective from many similar studies, but is limited to considering inter-organizational collaboration of the formal nature.

The use of the POL-on system base enabled the acquisition of objective, measurable, standardized and complete data (which results from the reporting obligation of Polish scientific units). However, it should be remembered that the collected information determines the egocentric nature of the presented network, which limits the possibility of inference only in the context of Poland, as well as the relatively short period analysed and the static approach presented in the research results. Conducting similar research in dynamic terms (taking into account the change in the network structure over time) may provide further conclusions as to the nature of undertaking international scientific collaboration of Polish institutions.

## References

- Abramo, G., D'Angelo, C. A., and Di Costa, F. (2009). Research collaboration and productivity: is there correlation? *Higher Education*, (57), 1551-171. <https://doi.org/10.1007/s10734-008-9139-z>
- Bammer, G. (2008). Enhancing research collaborations: three key management challenges. *Research Policy*, (37), 875-887.
- Batorski, D., and Zdziarski, M. (2009). Analiza sieciowa i jej zastosowania w badaniach organizacji i zarządzania. *Problemy Zarządzania*, 26(4), 157-184.
- Czakon, W. (2012). *Sieci w zarządzaniu strategicznym*. Warszawa: Wolters Kluwer.
- De Nooy, W., Mvar, A., and Batagelj, V. (2005). *Exploratory social networks analysis with Pajek*. Cambridge: Cambridge University Press.
- Hicks, D. J., Coil, D. A., Stahmer, C. G., and Eisen, J. A. (2019). Network analysis to evaluate the impact of research funding on research community consolidation. *PLoS ONE*, 14(6). <https://doi.org/10.1371/journal.pone.0218273>
- Hofman, I. (2015). Umieędzynarodowienie uczelni – jak to zrobić dobrze? *Nauka*, (1), 135-144.
- Katz, J. S., and Martin, B. R. (1997). What is research collaboration? *Research Policy*, (26) 1-18.

- Kwiek, M. (2020). Międzynarodowa współpraca badawcza w Europie w świetle dużych danych i jej globalne konteksty. *Nauka*, (1), 7-38.
- Olechnicka, A., Płoszaj, A., and Celińska-Janowicz, D. (2019). *The geography of scientific collaboration*. London–New York: Routledge.
- Rozporządzenie Ministra Nauki i Szkolnictwa Wyższego z dnia 29 czerwca 2015 r. w sprawie Systemu Informacji o Nauce (Dz. U. poz. 944).
- Ustawa z dnia 3 lipca 2018 r. – Przepisy wprowadzające ustawę – Prawo o szkolnictwie wyższym i nauce (Dz. U. z 2018 r. poz. 1669).
- Ustawa z dnia 30 kwietnia 2010 r. o zasadach finansowania nauki (Dz. U. z 2014 r. poz. 1620, z późn. zm.).
- Waltman, L., Tijssen, J. W., and van Eck, N. J. (2011). Globalisation of science in kilometres. *Journal of Informetrics*, (5), 574-582. <https://doi.org/10.1016/j.joi.2011.05.003>
- Wanzenböck, I., Scherngell, T., and Brenner, T. (2014). Embeddedness of regions in European knowledge networks: a comparative analysis of inter-regional R&D collaborations, co-patents and co-publications. *Annals of Regional Sciences*, (53).
- Woldegiyorgis, A. A., Proctor, D., and de Wit, H. (2018). Internationalization of research: Key considerations and concerns. *Journal of Studies in International Education*, 22(2), 161-176. <https://doi.org/10.1177/1028315318762804>

## WSPÓŁPRACA MIĘDZYNARODOWA POLSKICH PODMIOTÓW BADAWCZYCH W KONTEKŚCIE TERYTORIALNYM

**Streszczenie:** Celem artykułu było scharakteryzowanie struktury współpracy naukowej uruchomionej przez polskie instytucje w partnerstwie z podmiotami zagranicznymi w 2019 r., z uwzględnieniem kontekstu terytorialnego. Dokonano analizy sieci wygenerowanej na podstawie danych zamieszczonych w systemie POL-on: wskazano komponenty (*weak components*), obliczono stopień wierzchołka oraz pośrednictwo (*betweenness centrality*) dla każdego podmiotu, zidentyfikowano istotne powiązania w sieci zredukowanej do poziomu krajów oraz województw. Rozpoznano kluczowy podmiot w sieci (Główny Instytut Górnictwa). W rozpatrywanej sieci wyraźnym pośrednictwem cechują się także podmioty zagraniczne. Na poziomie relacji między państwami zaobserwowano dużą gęstość sieci oraz znaczną aktywność instytucji z Niemiec, co w przyszłości może utrudnić uzyskanie przewag. Współpraca naukowa polskich instytucji jest realizowana głównie z ośrodkami zlokalizowanymi w Europie, przy czym zasadniczo nie ma ona charakteru transgranicznego.

**Słowa kluczowe:** współpraca, naukometria, analiza sieci (SNA).