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Marcin Kardas[*]
Wydział Zarządzania
Uniwersytet Warszawski

The bibliometric analysis of the research potential of the Research Network Lukasiewicz

Abstract. The establishment of the Research Network Lukasiewicz (RNL) is aimed at strengthening the research potential and knowledge transfer from research institutes to enterprises. The article presents the results of the research potential analysis of 38 research institutes that are to form the RNL, based on data on scientific publications in 2013–2016. The number of publications of RNL institutes was similar to the number of publications of TNO and VTT institutes but smaller than that of Fraunhofer institutes. The publications of RNL institutes had lower values of indicators of international collaboration and collaboration with business as well as lower values of citation indices. Co-authors of RNL publications were mainly affiliated with national scientific units, whereas co-authorship with Fraunhofer, TNO and VTT institutes was marginal. The article also outlines the limitations and challenges of the adopted research method and future research orientations in this area.

Key words: bibliometric analysis, Research Network Lukasiewicz, knowledge transfer, research, innovation, scientific publications

Analiza bibliometryczna potencjału badawczego Sieci Badawczej Łukasiewicz

Abstrakt. Wzmocnienie potencjału badawczego i transferu wiedzy z instytutów badawczych do przedsiębiorstw jest jednym z celów utworzenia Sieci Badawczej: Łukasiewicz. W artykule przedstawiono wyniki analizy potencjału badawczego 38 instytutów badawczych, które mają znaleźć się w SBŁ w oparciu o dane dotyczące publikacji naukowych z lat 2013–2016. Liczba publikacji instytutów SBŁ była zbliżona do liczby publikacji instytutów TNO i VTT, ale mniejsza niż instytutów Fraunhofer. Publikacje instytutów SBŁ miały niższe wartości wskaźników współpracy międzynarodowej oraz współpracy z biznesem, a także wskaźników cytowalności. Współautorzy publikacji SBŁ pochodzili głównie z krajowych jednostek naukowych, zaś współautorstwo z instytutami Fraunhofera, TNO i VTT miało charakter marginalny. W artykule przedstawiono także ograniczenia i wyzwania przyjętej metody badawczej oraz przyszłe kierunki badań w tym zakresie.

Słowa kluczowe: analiza bibliometryczna, Sieć Badawcza Łukasiewicz, transfer wiedzy, badania, innowacje, publikacje naukowe

Introduction

In many countries, research and development activities focused on collaboration and knowledge transfer to industry are implemented by organisations set up for this purpose, referred to as research institutes or technological research organi-

[*] For correspondence: Wydział Zarządzania UW, ul. Szturmowa 1/3, 02-678 Warszawa, e-mail: mkardas@wz.uw.edu.pl

sations (Gijsbers et al. 2005; OECD 2011; EARTO 2015). In Germany, these are the institutes brought together within the Fraunhofer Society, in Finland – within VTT Technical Research Centre of Finland Ltd (VTT), and in the Netherlands – within the Netherlands Organisation for Applied Research (TNO). The above examples inspired the restructuring and integration of research institutes in many other countries, for instance RISE Research Institutes of Sweden (OECD 2016) In France, the potential of institutes is to be enhanced through collaboration based on a network model – Carnot Institute Network (OECD 2014). In Great Britain, where no typical research institutes were in place, research networks aimed at strengthening collaboration with industry are established on the basis of existing academic centres and referred to as Catapult Centres (Hauser 2014).

In Poland, research and development activities focused on collaboration with industry are the primary task of research institutes. Form the 1990s onwards, institutes were restructured and consolidated. In 2016–2017, the next restructuring stage was proposed, namely the establishment of the National Institute of Technology, with the Research Network Lukasiewicz to follow. In the works on the reform of research institutes, numerous references were made to examples of foreign organisations such as Fraunhofer, VTT or TNO institutes (Gulda et al. 2017; PAR 2018). These comparisons provided an inspiration for the following question to be asked: what is the scientific activity of the institutes that would form the Research Network Lukasiewicz as collated with foreign research organisations?

This article aims to examine the research potential of RNL, Fraunhofer, TNO and VTT institutes, based on a bibliometric analysis of scientific publications. The following sections depict the origins and evolution of the idea of RNL establishment, the assumptions of the adopted research method, and the research results. The article also attempts to identify the key competences and partners of RNL institutes. The final part outlines the conclusions regarding the activities of RNL institutes, drawn from the conducted research. The limitations and challenges of the proposed research approach and possible future research orientations in this respect are also discussed.

The origins and evolution of the idea of Research Network Lukasiewicz

The origins of research institutes currently operating in Poland date back to the beginning of the 20th century (e.g. Industrial Chemistry Research Institute, Institute of Precision Mechanics), although most of them were founded after 1945. Research institutes (R&D units before 2010) were and are supervised by competent ministries responsible for a given domain, hence they are also referred to as branch R&D institutes or government R&D sector (OECD 1996). In 1989, 297 R&D units operated in Poland, that number having fallen to about 240 after 10 years as a result

of restructuring (Jasiński, Okoń-Horodyńsk 2002). In consequence of consolidation and liquidation processes in subsequent years, 114 research institutes were active in 2017 (EC 2017) The 2016 "Strategy for Responsible Development" pointed out that "research institutes are insufficiently implementing their mission of bringing science closer to business", and in order to change this situation, it is necessary to "consolidate content-related and strategic supervision over the activities of research institutes and link these activities with strategic interests of the Polish state" (GOV 2016). The mechanisms of knowledge transfer to enterprises were to be improved through the establishment of the National Institute of Technology formed on the basis of existing institutes as an "integrator of the matrix network of research centres" (GOV 2016). The initial goals of the reform of research institutes were to set up a single entity integrating research institutes that would lose their legal personality. This concept evolved in 2016–2017, with the proposal to found the Research Network Lukasiewicz as the final outcome of expert work and community consultations (EC 2017). Under this framework, it is planned to set up a Network Centre responsible for coordinating its work. Institutes comprised by the Network retain legal personality and employees still have their existing rights. The primary goal of the RNL will be to carry out research work that is crucial from the point of view of Poland's policy, to commercialise research results, and to support Poland's economic policy, notably by forecasting trends and effects of technological changes that may have a strong impact on society and its development and by analysing the state of the art for the purposes of public policies (PAR 2018). In January 2018, a draft law on the establishment of the RNL was referred to the Parliament of the Republic of Poland (*Sejm*), which is conducting further legislative works.

Research method

The evaluation of the outcomes of research organisations' activities can rely, among others, on data concerning scientific publications, patents, licenses, spin-offs, joint research projects or commissioned research (OECD 2011; Kozłowski 2017). In this article, scientific publication data are used to assess the scientific potential of RNL, Fraunhofer, VTT and TNO institutes as well as to identify the key competences and crucial foreign and national partners. Publications are an important channel for dissemination of scientific research outcomes and knowledge transfer, and joint publications with enterprises may indicate strong links and long-term collaboration (Perkmann, Walsh 2006; OECD 2011). Scientific publications have been repeatedly analysed to assess the potential of Fraunhofer, VTT and TNO institutes (Solberg 2012; Loikkanen et al. 2013; Jonkers et at. 2017). On the other hand, scientific publications are primarily the result of scientific activities in the area of basic research. As a rule, industrial research and development works carried out jointly with or for enterprises rely on confidentiality of research outcomes or on patent protection of

these outcomes (Klincewicz et al. 2011). As a consequence, scientific publications may not be an appropriate indicator to assess the activity of some research institutes for which patents, joint research projects or commissioned research play a more important role. This limitation should be taken into account when interpreting the results of analyses concerning scientific publications produced by research institutes.

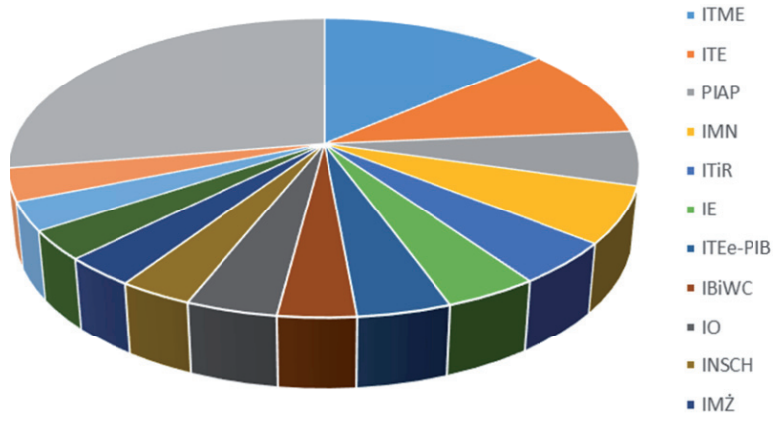
The largest global databases of scientific publications include Scopus and Web of Science. The Scopus database was chosen for this analysis since it offered more profiles and publications regarding research institutes as of the data retrieval day (24 February 2018). The Scival tool was used to carry out the analyses (it is based on data from Scopus). The examination covered all types of scientific publications such as articles, reviews, conference papers. It included scientific publications from 2013–2016 concerning 38 research institutes that are to be part of the RNL as stipulated by the draft law (PAR 2018). The institutes are listed in Appendix I.

The data on publications produced by RNL institutes were compared with those concerning the Fraunhofer Society institutes (Fraunhofer institutes) as well as TNO and VTT institutes. For the purposes of the research, 38 profiles of RNL institutes were first developed. The profiles were created based on the affiliations of the authors of publications. For 12 institutes, profiles available in the Scopus database were used. For the remaining 26 institutes, individual profiles were drawn up that took into account various affiliations provided in institute publications (e.g. Polish and English versions and abbreviations). On that basis, 3613 scientific publications of the examined research institutes in 2013–2016 were identified. The next step involved the development of the RNL profile covering publications produced by the institutes that would be comprised by the RNL, and an analogous profile of RNL was created in Scival. With such RNL profile, 3341 publications were found in Scopus (publications co-authored exclusively by employees of at least two RNL institutes are counted separately, hence fewer publications than the number mentioned above). In turn, after transferring those publications from Scopus to Scival, the number of RNL publications was 3320 (21 publications were not transferred from Scopus to Scival for technical reasons). The profiles of Fraunhofer, TNO and VTT institutes available in Scopus and Scival were not verified. Data for those profiles were further analysed based on the indicators presented in Appendix II.

Research potential of the RNL according to bibliometric analysis

In 2013–2016, a total of 38 RNL research institutes published 3613 scientific works. Figure 1 illustrates their publication activity. The share of five institutes with the largest number of publications was about 40% of publications produced by RNL institutes, and that of ten institutes was approximately 60%. In the period under examination, five institutes published 10 or fewer publications available in the Scopus database.

Figure 1. Publication activity of RNL institutes (abbreviations – Appendix I)



Source: Prepared by the author on the basis of Scopus.

Taking into account 3341 publications in the Scopus database and 3320 publications in Scival, RNL institutes would rank 17th among Polish entities as regards the number of publications in 2013–2016. Table 1 reports basic data on Fraunhofer, VTT, TNO and RNL institutes.

Table 1. Basic data on Fraunhofer, VTT, TNO and RNL institutes (2013–2016)

Organisations	Indicators	Scholarly output			Collaboration (all publications)		Citation (including self-citation)			
		All publications	Articles	Conference papers	International collaboration	Academic-business collaboration	Cited publications	Field-weighted citation impact	Publications in Top Journal Percentiles	Output in top 10% citations
	Years				%	%	%		%	%
Fraunhofer	2013	3759	1649	1834	31,1	7,3	76,9	1,39	28,3	10,9
	2014	3956	1792	1934	30,6	6,6	74,5	1,37	28,8	10,4
	2015	3725	1649	1769	32,3	6,7	69,3	1,4	28,1	11,3
	2016	3652	1727	1660	33,7	6,8	59	1,35	27,2	11,4
	2013-2016	15092	6817	7197	31,9	6,9	70,1	1,38	18,1	11
VTT	2013	1126	483	365	38,7	4,4	82,6	1,47	37,4	15,7
	2014	1099	593	352	41,3	5	79,1	1,72	36,6	14,8
	2015	918	570	284	43,9	4,6	79,8	1,53	38,6	15,4
	2016	892	440	347	49,7	5,5	60,1	1,28	36,7	14,4
	2013-2016	4035	2086	1348	43	4,9	75,8	1,51	37,3	15,1
TNO	2013	910	591	428	43,7	6	82	1,55	33,9	13,9
	2014	1017	621	377	48,5	6,6	80	1,56	35,2	17,1
	2015	922	576	263	49,1	7,1	78,3	1,48	39,1	14,2
	2016	853	528	270	46,7	6,1	66,7	1,65	40,1	16,1
	2013-2016	3702	2316	1338	47,1	6,4	77,2	1,56	36,9	15,3
RNL	2013	734	513	192	20	*17,3*	68,5	0,7	10,5	4,5
	2014	807	595	189	19	*19,3*	67,7	0,7	12,7	5,3
	2015	867	653	186	19,5	*14,3*	62,5	0,68	15,1	7,6
	2016	912	611	248	22,1	*12,1*	51,5	0,86	13	6,8
	2013-2016	3320	2372	815	20,2	*15,6*	62,1	0,74	12,9	6,1

Shaded cells indicate the highest indicator in a given year; cells marked in italics are erroneously assigned affiliations of enterprises in Scival (to be excluded from analysis).

Source: Prepared by the author on the basis of Scopus and Scival.

In 2013–2016, Fraunhofer institutes were distinguished by the largest number of scientific publications, including the greatest number of articles and conference papers. The publications of Fraunhofer institutes were dominated by conference papers (except 2016), which highlights the importance of conferences as their major channel of knowledge transfer. Other institutes recorded much fewer publications in the period concerned. As regards VTT and TNO publications, scientific articles prevailed. The number of RNL publications increased in 2013–2016, outnumbering VTT and TNO publications in 2016. As concerns the type of publications, RNL publications included the smallest share of conference papers in relation to scientific articles among the analysed organisations.

Considering the internationalisation of scientific output, TNO (47%) and VTT (43%) had the highest shares of publications with foreign co-authors in 2013–2016. Foreign co-authorship levels were lower in the case of Fraunhofer (31.9%) and RNL (20.2%) institutes. The Scival data on collaboration within institutions and at the national level contain erroneous assignment of publications for the RNL, thus they were not analysed (many joint publications with other entities were defined as institutional collaboration).

Fraunhofer institutes were marked by the highest share of 2013–2016 publications whose co-authors represented enterprises. RNL data cannot be included based on Scival due to erroneous assignment of business affiliations to some RNL institutes (e.g. ITME). According to Author's estimates, the share of RNL publications co-authored by business representatives was about 1%. The values of this indicator should, however, be interpreted with caution also in relation to other organisations since the presented values may be overstated.

In 2013–2016, TNO publications recorded the highest share of cited publications in total publications (71.2%), the highest citation ratios for publications of an organisation relative to world citations in the subject field – FWCI (1.28), and the highest share of top 10% world citation in all publications of an organisation (13.1%). This proves high recognisability of TNO scientific publications. VTT publications had slightly lower values of these indicators. VTT and TNO had similar shares of publications published in the world's top journals. A greater number of Fraunhofer publications did not translate into higher citation indices as compared to VTT and TNO. In the case of RNL publications, FWCIs and shares of most cited publications in 2013–2016 increased, yet were significantly lower than for the other organisations under analysis. This implies that the publication potential of RNL institutes was quantitatively comparable with that of VTT and TNO, but it definitely lagged behind them as regards recognisability and citation indices.

Table 2 presents key partners of RNL. These were primarily national technical universities. The group of 20 partners with the highest number of joint publications included only one partner from outside Poland (the French CNRS).

Table 2. National and foreign organisations of co-authors of RNL publications (2013–2016)

No	Partners	Publications	FWCI	No	Partners	Country	Publications	FWCI
1	Warsaw University of Technology	387	0,93	17	National Centre for Scientific Research (CNRS)	France	32	1,06
2	Polish Academy of Sciences	334	0,77	24	Czech Academy of Sciences	Czech Republic	24	1,37
3	University of Warsaw	223	0,86	29	University of Paris-Saclay	France	21	0,94
4	Silesian University of Technology	217	1,26	32	Heriot-Watt University	UK	19	0,7
5	AGH University of Science and Technology	199	0,74	37	Alternative Energies and Atomic Energy Comission (CEA)	France	16	1,59
6	Łódź University of Technology	150	0,47	40	Deutches Elektronen-Synchrotron DESY	Gemrany	15	0,28
7	Wrocław University of Science and Technology	128	1,2	47	National Institute of Nuclear and Particle Physics (IN2P3)	France	12	0,7
8	University of Silesia	107	0,88	49	Lvic Polytechnic National University	Ukraine	12	0,7
9	Military University of Technology in Warsaw	88	1,07	50	University of Rochester	US	12	0,77
10	Poznań University of Technology	65	1,08	51	Technische Universitat Dresden	Germany	11	0,71

Source: Prepared by the author on the basis of Scival.

RNL institutes released most joint publications with authors representing Warsaw University of Technology (over 10%), institutes of the Polish Academy of Sciences, and the University of Warsaw. As regards FWCI, the most valuable collaboration was pursued with the French CEA, the Czech Academy of Sciences, the Silesian University of Technology and Wrocław University of Science and Technology. Among the analysed RNL publications, 14 were published jointly with authors from Fraunhofer institutes (the institutes were examined separately, not as one entity, hence they are not included in Table 2) and two were published with co-authors from TNO. In the period under analysis, no joint publications of RNL institutes with authors representing VTT were identified in the Scopus database (yet, joint publications with VTT were released by universities, mainly technical ones).

Table 3 reports data on publications released by the analysed organisations and FWCIs in various fields of All Science Journal Classification (ASJC) used in the Scopus database (2012–2016). In terms of the number of publications, Fraunhofer institutes dominated in all fields, except for medicine, where TNO had the largest number of publications. The specialisation of TNO in medicine, pharmacy and biology is also confirmed by the highest indices of revealed technology advantage (RTA) in these fields. According to the RTA index, RNL institutes specialised in chemical engineering, chemistry and materials science, as viewed against the backdrop of the examined organisations. Considering FWCI, Fraunhofer institutes were leaders in the fields of engineering, computer science and energy. TNO publications recorded the highest FWCI indices for materials science, chemistry, mathematics, environmental science, agricultural science and social science, while VTT publications had the highest FWCIs for physics and astronomy, chemical engineering, biochemistry, medicine and pharmacology. In turn, Fraunhofer institutes recorded

the highest values for, among others, engineering and computer science, namely the fields in which they also released numerous scientific publications. This evidences scientific specialisation as well as high recognisability of the publication activity of these organisations in the indicated fields.

Table 3. Publications and FWCI in major ASJC fields (2012–2016)

	Materials science	Engineering	Physics and Astronomy	Chemistry	Chemical Engineering	Computer science	Biochemistry, genetics and molecular biology	Mathematics	Environmental science	Energy	Medicine	Pharmacology, toxicology and pharmaceutics	Agricultural and biological sciences	Social sciences	Total publications
Number of publications 2012-2016															
Fraunhofer	5848	8703	5505	1707	941	5665	1038	2427	683	1172	945	267	456	506	18729
VTT	978	1684	922	469	436	1000	496	340	348	579	372	49	384	213	4605
TNO	645	1515	726	297	191	1024	435	521	442	347	1135	221	320	370	5099
RNL	1898	1821	1276	822	648	502	229	210	182	133	119	104	98	23	4098
RTA - publications															
Fraunhofer	1,08	1,10	1,13	0,90	0,74	1,20	0,82	1,21	0,72	0,91	0,64	0,72	0,63	0,79	1,00
VTT	0,74	0,87	0,77	1,01	1,39	0,86	1,59	0,69	1,49	1,83	1,02	0,54	2,16	1,35	1,00
TNO	0,44	0,70	0,55	0,58	0,55	0,80	1,26	0,95	1,70	0,99	2,82	2,20	1,62	2,12	1,00
RNL	1,61	1,05	1,20	1,98	2,32	0,49	0,83	0,48	0,87	0,47	0,37	1,29	0,62	0,16	1,00
Field-weighted citations impact (FWCI)															
Fraunhofer	1,39	1,52	1,48	1,2	1,17	1,36	1,42	1,29	1,36	2,12	1,27	1,52	1,37	1,49	1,41
VTT	1,21	1,31	1,85	1,26	1,26	1,13	1,47	1,41	1,83	1,69	1,74	1,81	1,53	1,48	1,47
TNO	1,52	1,48	1,37	1,37	0,85	1,34	1,41	1,55	2,07	1,65	1,72	1,7	1,9	2,17	1,57
RNL	0,69	0,78	0,89	0,6	0,34	0,94	2,76	0,87	0,61	0,87	0,69	0,89	0,81	1,18	0,85

Source: Prepared by the author on the basis of Scival.

RNL institutes had lower FWCIs in most of analysed ASJC fields in comparison with Fraunhofer, VTT and TNO institutes. In two cases did FWCI exceed 1 and the highest values of FWCIs were recorded for biochemistry, genetics and molecular biology, social sciences, computer science, physics and astronomy, mathematics and energy, with lower values for materials science and engineering, although RNL had the largest number of publications in the latter two fields. RNL institutes also had a smaller share of publications in computer science (13%) as compared to Fraunhofer (30%), VTT (22%) and TNO (20%) institutes. They also released far fewer publications in social science. Although the latter are not directly related to the area of RNL activity, they may nevertheless be important from the perspective of the social impact of research and the dissemination of research outcomes.

Conclusions

The analysis of the research potential of RNL institutes shows that bibliometric data can be used to analyse the publication achievements and output of existing organisations as well as of non-existent organisations and those "created" solely for the purposes of bibliometric analyses. However, the results of such a simulation

should be interpreted with particular caution since the comparison covered existing organisations (Fraunhofer Society, VTT and TNO) that have for years operated on the basis of stable structures and principles ensuring coordination, synergies and coherence of activities and a non-existent organisation (RNL) "created" for the purposes of this analysis. Based on the comparisons of their publication activity, the strengths and weaknesses of RNL institutes were identified as shown in Table 4.

Table 4. Strengths and weaknesses of RNL as compared to Fraunhofer, TNO and VTT institutes

Strengths	Weaknesses
A growing number of scientific publications (higher than for VTT and TNO in 2016)	Weak internationalisation of publication activity (low share of joint publications with foreign authors)
Involvement in collaboration with national universities, mainly technical ones	Low recognisability of the publication output (lower citation indices)
Relative specialisation (RTA) in chemical engineering, chemistry and materials science	No field specialisation confirmed by high recognisability (citation indices) of publications

Source: Prepared by the author.

As revealed by the comparisons, RNL institutes, despite their constantly growing publication activity in 2013–2016 measured as the number of publications, were less engaged in international collaboration and their publication output was less recognised as compared to Fraunhofer, VTT and TNO institutes. Although these organisations cooperated with Polish scientific units as part of the publication activity, their collaboration with RNL institutes was negligible in the light of the analysed data. On the other hand, it should be taken into account that possible collaboration may be pursued in other forms such as joint patents or joint research projects the outcomes of which are confidential. Nevertheless, the strengthening of collaboration with foreign partners, including Fraunhofer, TNO and VTT institutes, should be among the RNL priorities.

The differences in the number of publications between RNL institutes show that scientific publications may not be an appropriate indicator to assess the scientific output of many institutes. In the case of some research institutes (e.g. ITME, ITE, PIAP), scientific publications are, however, an important aspect of their scientific activity, which should be considered when devising the future evaluation and financing system for RNL institutes.

The presented results should be treated as preliminary (pilot), notably given the limitations related to the assignment of affiliations of individual institutes, different field profiles of the examined organisations, and their involvement in basic and application research. Future research should be extended to include analyses of the Web of Science and patent data. This will produce a fuller picture of the activity and scientific potential of RNL institutes.

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Appendix I
List of institutes to form the Research Network Lukasiewicz

	Polish name	English name	Abbreviation
1	Centralny Ośrodek Badawczo-Rozwojowy Maszyn Włókienniczych „Polmatex-Cenaro" w Łodzi	Research and Development Centre of Textile Machinery "Polmatex-Cenaro"	CENARO
2	COBRO – Instytut Badawczy Opakowań w Warszawie	COBRO – Polish Packaging Research and Development Centre	COBRO
3	Instytut Biopolimerów i Włókien Chemicznych w Łodzi	Institute of Biopolymers and Chemical Fibres	IBiWC
4	Instytut Biotechnologii i Antybiotyków w Warszawie	Institute of Biotechnology and Antibiotics	IBA
5	Instytut Ceramiki i Materiałów Budowlanych w Warszawie	Institute of Ceramics and Building Materials	ICMB
6	Instytut Chemii Przemysłowej imienia Profesora Ignacego Mościckiego w Warszawie	Industrial Chemistry Research Institute	ICHP
7	Instytut Ciężkiej Syntezy Organicznej „Blachownia" w Kędzierzynie-Koźlu	Institute of Heavy Organic Synthesis "Blachownia"	ICSCH
8	Instytut Elektrotechniki w Warszawie	Electrotechnical Institute	IE
9	Instytut Farmaceutyczny w Warszawie	Pharmaceutical Research Institute	IF
10	Instytut Inżynierii Materiałów Polimerowych i Barwników w Toruniu	Institute for Engineering of Polymer Materials and Dyes	IIMPiB
11	Instytut Logistyki i Magazynowania w Poznaniu	Institute of Logistics and Warehousing	ILiM
12	Instytut Lotnictwa w Warszawie	Institute of Aviation	IL
13	Instytut Mechaniki Precyzyjnej w Warszawie	Institute of Precision Mechanics	IMP
14	Instytut Mechanizacji Budownictwa i Górnictwa Skalnego w Warszawie	Institute of Mechanised Construction and Rock Mining	IMBiGS
15	Instytut Metali Nieżelaznych w Gliwicach	Institute of Non-Ferrous Metals	IMN
16	Instytut Metalurgii Żelaza im. Stanisława Staszica w Gliwicach	Stanislaw Staszic Institute for Ferrous Metallurgy	IMŻ
17	Instytut Napędów i Maszyn Elektrycznych KOMEL w Katowicach	Institute of Electrical Drives and Machines KOMEL	KOMEL
18	Instytut Nowych Syntez Chemicznych w Puławach	New Chemical Syntheses Institute	INSCH
19	Instytut Obróbki Plastycznej w Poznaniu	Metal Forming Institute	INOP
20	Instytut Odlewnictwa w Krakowie	Foundry Research Institute	IO
21	Instytut Optyki Stosowanej im. M. Pluty w Warszawie	Institute of Applied Optics	IOS

	Polish name	English name	Abbreviation
22	Instytut Organizacji i Zarządzania „ORGMASZ”	Organisation and Management Institute „ORGMASZ”	ORGMASZ
23	Instytut Pojazdów Szynowych „TABOR” w Poznaniu	Rail Vehicles Institute „TABOR”	TABOR
24	Instytut Przemysłu Organicznego w Warszawie	Institute of Industrial Organic Chemistry (IPO)	IPO
25	Instytut Przemysłu Skórzanego w Łodzi	Leather Industry Institute	IPS
26	Instytut Spawalnictwa w Gliwicach	Institute of Welding	IS
27	Instytut Technik Innowacyjnych EMAG w Katowicach	Institute of Innovative Technologies EMAG	EMAG
28	Instytut Techniki i Aparatury Medycznej ITAM w Zabrzu	Institute of Medical Technology and Equipment ITAM	ITAM
29	Instytut Technologii Drewna w Poznaniu	Wood Technology Institute	ITD.
30	Instytut Technologii Eksploatacji – Państwowy Instytut Badawczy w Radomiu	Institute for Sustainable Technologies – National Research Institute	ITEe-PIB
31	Instytut Technologii Elektronowej w Warszawie	Institute of Electron Technology	ITE
32	Instytut Technologii Materiałów Elektronicznych w Warszawie	Institute of Electronic Materials Technology	ITME
33	Instytut Tele- i Radiotechniczny w Warszawie	Tele and Radio Research Institute	ITiR
34	Instytut Włókiennictwa w Łodzi	Textile Research Institute	IW
35	Instytut Zaawansowanych Technologii Wytwarzania w Krakowie	Institute of Advanced Manufacturing Technology	IZTW
36	Przemysłowy Instytut Automatyki i Pomiarów w Warszawie	Industrial Research Institute for Automation and Measurements	PIAP
37	Przemysłowy Instytut Maszyn Rolniczych w Poznaniu	Industrial Institute of Agricultural Engineering	PIMR
38	Przemysłowy Instytut Motoryzacji w Warszawie	Motor Transport Institute	PIM

Source: Ministry of Science and Higher Education

Appendix II
Indicators applied in bibliometric analysis

Name	Description
Scholarly output	The number or all publications (articles, reviews, conference papers, editorials, short surveys, books and book chapters) of a selected entity.
International collaboration	The extent of international, national and institutional co-authorship (all publications).
Academic-business collaboration	Publications with both academic and corporate affiliations (all publications).
Cited publications	Publications that have received at least one citation.
Field-weighted citation impact	The ratio of citations received relative to the expected world average for the subject field, publication type and publication year (including self-citations).
Publications in top journal percentiles	The number of publications of a selected entity that have been published in the world's top journals.
Output in top citation percentiles	The number of publications of a selected entity that are highly cited, having reached a particular threshold of citations received.
Revealed Technology Advantage (RTA)	The revealed technology advantage (RTA) index provides an indication of the relative specialisation of a given organisation in selected ASJC domains and is based on scientific publications. It is defined as an organisation's share of publications in a particular domain divided by the organisation's share in all domains. The index is equal to zero when the organisation holds no publication in a given domain; is equal to 1 when the organisation's share in the domain equals its share in all publications (no specialisation); and above 1 when a positive specialisation is observed.

Source: Scival and OECD