Agnieszka Olechnicka[1]

Regional potential of Polish science
(on the basis of parametric evaluation by Ministry of Science and Higher Education as well as Web of Science database)

In a knowledge based economy the science sector has a major influence on regional development, including regional innovativeness. Although universities have long been perceived as institutions that provide basic science infrastructure and as a source of technological innovation, their role in creating knowledge used to be regarded as external in relation to production system. Cooperation between science and industry was viewed as incidental, while the process of innovation implementation happened along the lines of the linear science push model. That situation was changed by innovation system theories, which explore innovation born as a result of interaction among regional/national actors or those representing particular field/technologies: the science sector, the enterprise sector, the authorities, innovation support institutions and development support institutions. The above mentioned theories emphasise the non-linear character and the heterogeneity of knowledge creation processes and point out the inefficiency of linear innovation processes. Thus activity in the creation of knowledge began to be perceived as an inherent part of processes that take place (more and more frequently on the regional level) within the network of firms and other organizations, including universities (GUNASEKARA, 2006; OECD, 1997; COOKE, 1998; FREEMAN, 1991).

The influence that the science sector has on a region can assume diverse forms and have varied intensity, depending on numerous conditions, some of which are connected with the region's characteristics and others with the science research sector (GUNASEKARA, 2006; BOUCHER et al., 2003; MAYER, 2006; BENNEWORTH and HOSPERS, 2007). It seems that the following factors have a major bearing on innovativeness as far as the influence of the science sector is concerned: 1) the potential of the science sector in the region; 2) the extent in which the 'products' of the science sector are adjusted to the needs of the region; 3) the strength of the sector that assists in the flow of knowledge and innovation between science and economy.

[1] Assistant professor in the Centre for European Regional and Local Studies (EUROREG), Warsaw University, a.olechnicka@uw.edu.pl.

The study focuses on the first of the above-mentioned elements and is an attempt to estimate the level of Polish science in the regional context, to indicate strong and weak regions in terms of their scientific potential and to present the links between them. The article will endeavour to verify the research hypothesis that the potential of Polish science is regionally highly varied and that, consequently, the influence that science background has on the region is also of varied intensity. Indicators used in the analysis are of a broader scope than the traditionally used quantitative indicators such as the number of research institutions or expenditure and employment in R&D.

1. Science potential and regional innovativeness

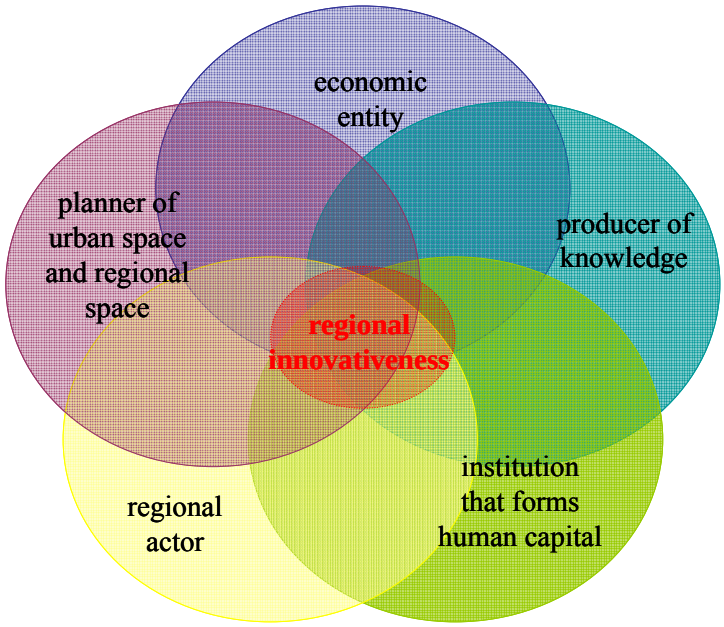
The views on the influence that science sector institutions and in particular universities[2] have on the regional environment constantly evolve and tend towards a more complex vision that takes into account not only economic effects of academic activity in the region, but also socio-cultural ones. The role of the university can be considered on five different planes: 1) the university as an economic entity, 2) the university as a producer of knowledge, 3) the university as an institution that forms human capital, 4) the university as a regional actor, 5) the university as a planner of urban space and regional space (BOUCHER et al., 2003; BENNEWORTH and HOSPERS, 2007; DRUCKER and GOLDSTAIN, 2007; GOLDSTEIN and RENAULT, 2004). The above functions cannot be, however, regarded separately. Some of the activities undertaken by science sector institutions lead to effects that belong to several of the mentioned areas at the same time. (DRUCKER and GOLDSTAIN, 2007).

It should be noted that all the functions – to various extents – concern science impact on regional innovativeness (Figure 1). The strongest impact on innovativeness is connected with the university's function as a producer of knowledge. This function concerns the creation of technological innovations, that is the making and commercialization of new products and processes within university environment, as well as innovation transfer (CASTELLS and HALL, 1994.). University is more and more frequently perceived as a link between the producers and the consumers of knowledge in a given area. If effectively transferred, this knowledge can innovatively strengthen enterprises of a given territorial system, its social organizations, government and self-government institutions and individual citizens (BERCOVITZ and FELDMAN, 2006).

[2] For the purpose of the paper worlds science institutions and universities will be use interchangeably.

Science sector influences regional innovativeness equally strongly as far as the formation of human capital is concerned. This attracts students and provides firms with qualified employees. The creation of human capital is strictly connected with the production of knowledge in the university. Human capital is formed as a result of raising the qualifications and the skills level not only of students but also of the academic staff and researchers. The creation of human capital is nowadays often connected with distance learning, with developing universities' entrepreneurial activity (embodied in the so called spin-off companies) or with universities' participation in local education schemes (BOUCHER et al., 2003).

Figure 1. Role of university in regional development.



Another important element in the construction of the innovative potential of a region is the science sector institutions' role as significant actors of the regional scene. This role is fulfilled by both formal and informal participation of higher education institutions and research institutes, along with other regional institutions, in the innovative process, in acquisition of knowledge and in the governance of a given area (BOUCHER et al., 2003). This function is also associated with active participation in producing so-called knowledge infrastructure, which is defined as a reserve of knowledge accompanied by institutional and organizational units that aid the growth of knowledge and its practical application. On a regional scale, knowledge infrastructure exceeds the simple sum of knowledge producing institutions and

should be understood as the capacity of firms, employees and institutions, as well as of the network that links these elements, to innovate and to learn (GOLDSTEIN and DRUCKER, 2006).

What merits particular attention is universities' influence on regional environment that manifests itself in the fact that universities' activities accumulate in a given territory well-qualified and creative employees and add up to specific local dynamics. For instance, Florida, in his concept of creative class claims that if a region is to attract high quality employees, be capable of generating innovation and stimulate economic growth, it must ensure three elements at the same time (the so-called 'three T's'): talent, technology and tolerance (FLORIDA, 2004). An ideal place does not have to be a metropolis, but it ought to provide its dwellers with an adequate number of recreational areas, to attract diverse groups of inhabitants (ethnically, occupationally, etc.) and to offer a rich cultural life – the so-called street life, cafes, clubs, museums, theatres and festivals within city space (FLORIDA, 2004).

Table 1. Role of university in regional innovation system development

Elements of regional innovation systems	Generative role (*triple helix)*	Developmental role (*engaged university*)
Regional agglomeration or clustering of industry	– Knowledge capitalisation and capital formation projects, centered on firm formation and co-location of new and existing firms near. university	– Entrepreneurial activities, a well as regionally focused teaching and research, not necessarily linker to capital formation projects
Human capital formation	– Integration of education and knowledge capitalization activities, specifically, firms formation, through teaching incubators – Development of generic, advanced training programs to support firm formation and cross-institutional mobility by organizations and people	– Stronger regional focus on student recruitment and graduate retention; – Education programs developed/adapted to meet regional skills needs; – Learning processes regionally informed
Associative governance	– Driver of regional innovation strategy, centred on knowledge capitalization and capital formation projects: by analysing strengths and weaknesses and bringing together industry and government to forge innovation strategy	– Shaping regional networking and institutional capacity, through staff participation on external bodies, provision of information and analysis to support decision making and brokering networking between national and international contacts and key regional actors
Regional cultural norms	– Tradition of university/industry linkages, involving knowledge capitalisation	– Tradition of university/industry linkages, involving knowledge capitalization and other research collaboration

Source: (GUNASEKARA, 2006).

A substantial portion of the literature concerning the role of universities in regional development is devoted to the ways in which HEIs bolster the growth of regional innovation system. Table 1 sums up the differences that exist between the two models which are discussed in the literature: the *triple helix* and the *engaged university* as far as universities' influence on particular elements of a regional innovation system is concerned. The former emphasises the generative role of universities, while the latter focuses on their developmental role (GUNASEKARA, 2006; HESSELS and VAN LENTE, 2008).

Although both models: 'the triple helix' and 'the engaged university' concern the so-called 'third role' of universities, which means involvement in regional development, they differ in terms of how they accentuate the character of university activity and its links with the other actors of the regional scene. The approach of an 'engaged university' is broader and goes beyond issues connected with setting up firms and the direct impact on economic growth. It stresses the significance of the capability of the university to attune to the region's needs and the willingness to cooperate with the environment. However, unlike in the 'triple helix' concept, universities' role is not equivalent to and replaceable by the role of industry and of the government (GUNASEKARA, 2006).

As was mentioned in the introduction, the strength of the science sector is crucial for the impact science has on a region. The following parts of the study are an attempt to determine the scientific potential of Polish voivodships on the basis of the parametric assessment by the Ministry of Science and Higher Education (MNiSW) and on the basis of an analysis of articles from the ISI Web of Science database.

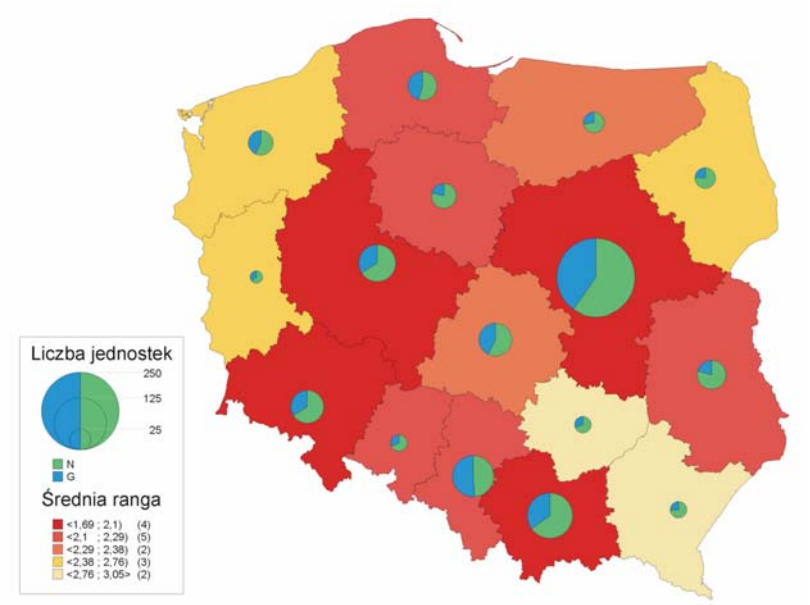
2. Scientific potential of regions on the basis of parametric evaluation by the Ministry of Science and Higher Education (MNiSW)

Using the parametric evaluation of academic units carried out by MNiSW[3] to present the scientific potential of regions is interesting in that this assessment is based on multiple criteria. Academic units are evaluated in groups which are homogeneous in terms of the area or areas of scientific research. Firstly, the evaluation concerns the results of scientific activity, i.e. reviewed publications, scientific monographies and academic textbooks written by the employees of a given unit, and also the units' right to award degrees. Secondly, the evaluation

[3] The parametric evaluation of scientific units is conducted every four years on the basis of MNiSW decree of October 17th 2007 on the criteria and mode of awarding and accounting for statutory activity funds (Journal of Laws No. 205).

takes into account practical use of research results and developmental projects, i.e. new technologies, materials, products, systems, services and methods; implementation of scientific research results and developmental projects; patents, licences, utility models protection laws, and also the possession of laboratories accredited by Polish Centre for Accreditation (Official web site MNiSW).

Map 1. Parametric evaluation of science units (2006).



Source: calculation by T. Wronka on the basis of MNiSW data.

A weakness of the parametric evaluation is the fact that it is based on information included in questionnaires filled in by the academic units themselves according to a common form. The information is not verified or made objective by the Ministry.

As a result each science unit is awarded a category from 1 to 5, where 1 is the highest category. All science units are divided according to the type of conducted research into two groups: 'science' (N) and 'economy' (G). Each group is measured with different weighting factors for scientific activity and practical utilisation of research.

Map 1 visualises average evaluation scores of 880 science units (excluding museums and libraries) from a regional perspective, 62% of which are institutions from the 'science' category. The highest average was achieved by science units from Dolnośląskie Voivodship (1,7) Mazowieckie Voivodship (1,8), Wielkopolskie Voivodship (1,8) and Małopolskie Voivodship (1,9). The weakest are Podkarpackie Voivodship (3,0) and Świętokrzyskie Voivodship (2,8).

These results indicate that determining the scientific potential of voivodships based on the number of HEIs or science-research institutions can be misleading as some voivodships seem to have a stronger scientific potential than it could be expected judging by the number of science institutions (Dolnośląskie, Wielkopolskie, Lubelskie, Kujawsko-Pomorskie, Opolskie, Lubuskie), while the scientific potential of others is weaker (Mazowieckie, Małopolskie, Śląskie, Łódzkie, Pomorskie, Zachodniopomorskie, Podkarpackie) than expected. For example, the ranking leader – Dolnośląskie Voivodship – is sixth for the number of assessed science institutions, while Śląskie Voivodship, which is ranked third for the number of science institutions, is only in the seventh place in the parametric evaluation.

The map also makes it possible to study the structure of science units in particular voivodships. It is clearly visible that in most voivodships units from the category 'science' prevail and that the greatest share of these characterises eastern voivodships: Podlaskie, Lubelskie, Podkarpackie and Swiętokrzyskie, and also Opolskie, Kujawsko-Pomorskie and Warmińsko-Mazurskie. Whereas Śląskie, Pomorskie, Zachodniopomorskie and Mazowieckie boast relatively greatest shares of the category 'economy' in the total number of science units.

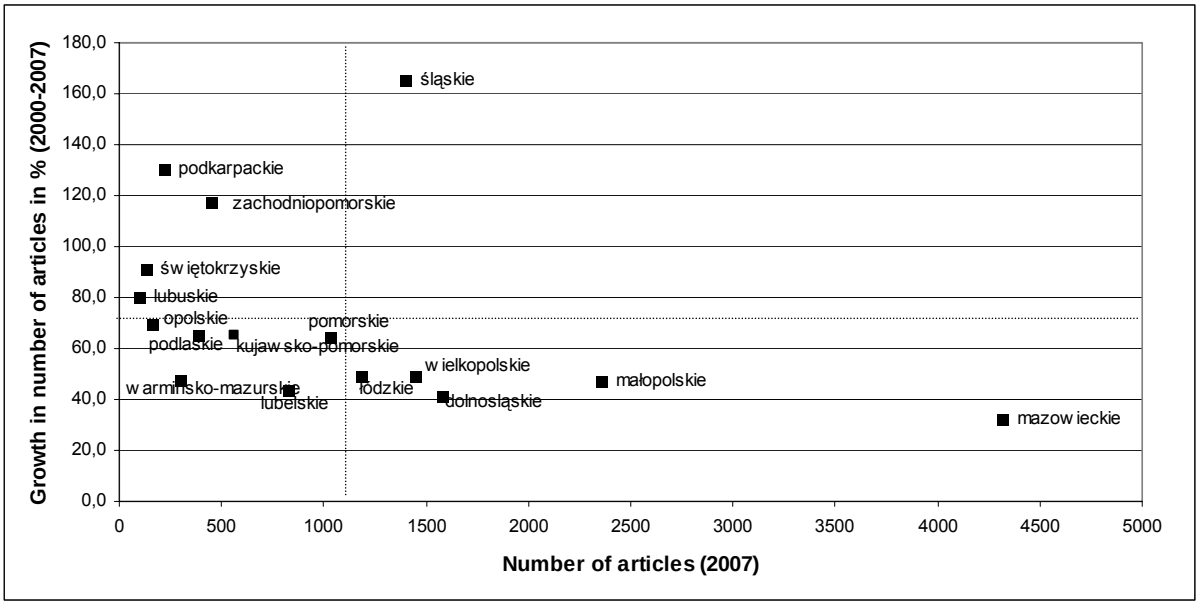
3. Scientific potential on the basis of ISI Web of Science database

Analysing publications and citations is a difficult task, fraught with interpretation ambiguities. However, such analysis is valuable because they measure the effects of science sector activity. It is also worth remembering that they give evidence to scientific activity and are used by e.g. international institutions and organizations to assess the scientific standing of particular countries (WRÓBLEWSKI, 2001).

Regional analyses were performed based on the ISI Web of Science database created by the Thomson Scientific Limited in a three-part version: Science Citation Index Expanded (SCI Ex), Social Science Citation Index (SSCI), Arts and Humanities Citation Index (AHCI)3. The database draws from publications included in over 11 000 titles of scientific journals. One characteristic of the database is the prevalence of articles concerning sciences (SCI Ex). In Poland in 2007 such articles made up 98% of all the database's works of this type.

The presented data concerns exclusively articles which were searched by means of the authors' addresses (author affiliation). Because many articles (it is difficult to estimate their exact number on the basis of the analysis) are co-written, the total number of publications in particular voivodships is greater than the total number of publications that have at least one Polish author.

Figure 2.Number of articles with Polish affiliation and their growth in the years 2000-2007.



Source: own calculation on the basis of the Web of Science database.

Mazowieckie Voivodship is a definite leader in the number of articles in the particular years of the 2000-2007 period. Further down the ranking there are Małopolskie, Dolnośląskie, Wielkopolskie i Śląskie. All the mentioned voivodships with the exception of Śląskie, are conspicuous for poor dynamics in the number of publications. Beside Śląskie, Zachodniopomorskie and Podkarpackie stand out in this respect as voivodships characterized by a relatively low number of articles (over 100% within 7 years).

If we take into account the mean value of the two analysed indicators, all the voivodships depicted on Figure 2 can be roughly divided into four groups. Among voivodships with the highest potential in terms of publications number is Śląskie, which has not only higher than average number of publications, but also the highest rate of growth in their number in the years 2000-2007. Whereas the least promising group are voivodships which are closest to the beginning of the coordinate system, characterised by a scarcity of articles combined with poor dynamics of growth in their number (Warmińsko-Mazurskie, Lubelskie, Opolskie, Podlaskie, Kujawsko-Pomorskie i Pomorskie).

When interpreting publications dynamics, it should be remembered that an increase in the number of publications attributed to a given voivodship is not only a result of greater activity of its science environment, but that it also depends, to a certain extent, on the number of journal titles comprised in the Web of Science database, which is increasing yearly.

Table 2. Indicators for science productivity by voivodship

Voivodship	Number of citations in 2007 of articles from the period 2000-2007			number of articles per employed in R&D	
	total	per employed in R&D in 2006	per article from the period 2000-2007	in 2000	in 2006
Dolnośląskie	11 296	1.28	0.99	0.12	0.19
Kujawsko-pomorskie	4 203	0.87	1.14	0.07	0.12
Lubelskie	5 393	0.75	0.95	0.08	0.12
Lubuskie	497	0.47	0.75	0.04	0.09
Łódzkie	8 416	1.09	1.07	0.09	0.14
Małopolskie	21 557	1.61	1.31	0.10	0.18
Mazowieckie	41 605	1.24	1.31	0.09	0.13
Opolskie	644	0.42	0.62	0.06	0.08
Podkarpackie	946	0.30	0.74	0.03	0.07
Podlaskie	2 881	1.22	1.11	0.10	0.11
Pomorskie	8 872	1.29	1.29	0.09	0.16
Śląskie	8 824	0.76	1.21	0.05	0.11
Świętokrzyskie	890	0.72	1.12	0.06	0.09
Warmińsko-mazurskie	2 446	1.17	1.19	0.10	0.14
Wielkopolskie	10 350	0.83	1.04	0.08	0.12
Zachodniopomorskie	2 826	0.80	1.02	0.06	0.14

Source: own calculation on the basis of the Web of Science database.

While the number of articles is the greatest in Mazowieckie Voivodship, the relative value per person employed in R&D is the highest in Dolnośląskie Voivodship (0,19), Małopolskie Voivodship (0,18) and Pomorskie Voivodship (0,1). All regions recorded an increase in the analysed indicator in the years 2000-2006, while Zachodniopomorskie, Podkarpackie and Śląskie are, in this respect, characterised by the highest dynamics (more than a twofold increase). The voivodships with the lowest productivity of the science sector, as measured by the number of articles in the Web of Science per person employed in R&D, include: Podkarpackie (0,07) and Opolskie (0,08), whereas the weakest dynamics can be observed in Podlaskie Voivodship (an increase by only 11%).

A dynamic analysis of the number of citations on a regional level is more problematic and arduous because of the limitations of the database itself. An interpretation of citations indicators is also difficult, but many researchers emphasise that it is a better measuring instrument than the number of publications. Citations are in a sense an offshoot of the number of publications. Therefore both the number of citations per R&D employee and the number of articles are the highest in Małopolskie, Pomorskie and Dolnośląskie, while the lowest in Opolskie and Podkarpackie.

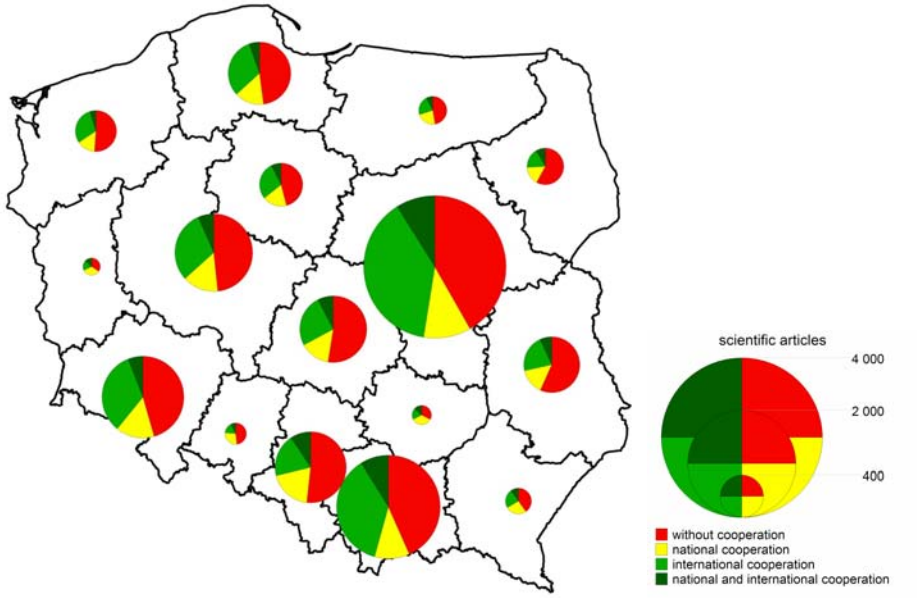
A measure that to a certain degree proves the significance, or the popularity, of an article is the average number of citations per publication. Here the highest indicators were achieved

by Mazowieckie, Małopolskie and Pomorskie, but also Warmińsko-Mazurskie and Śląskie. The least frequently cited publications come from Podkarpackie, Opolskie and Lubuskie. In every interpretation of this kind of results it is crucial to note the share of articles from particular fields of knowledge as each field is characterised by a different average number of citations per article. Such analyses, however, are beyond the scope of this article.

4. Regional interrelations on the basis of ISI Web of Science

The analyses of publications and citations also served the purpose of outlining a network of cooperation between particular cities and voivodships. The authors analysed 13 416 articles in whose writing at least one person from a Polish science institution was engaged. The objective was to answer the following questions: 1) In what cooperation configurations are articles written in Poland created? 2) Which regions cooperate most closely? 3) Which regions are the most involved in international cooperation in this field?

Map 2. Share of institutions from particular regions in the writing of particular articles, 2007 r.



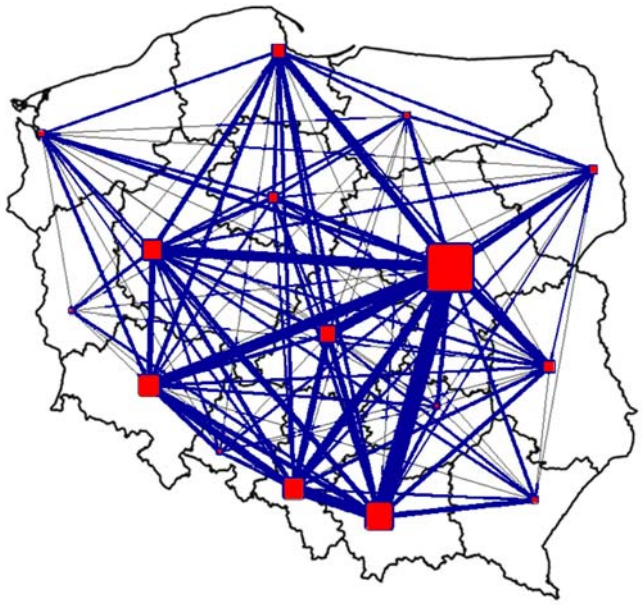
Source: calculation by A.Olechnicka i A. Płoszaj on the basis of the ISI Web of Science database.

Map 2 presents, firstly, the number of articles attributed to a voivodship in 2007 (the size of the circle); secondly, the colours denote the share of articles written within a given voivodship in cooperation with science institutions situated in other regions, in international cooperation and with contributions from national (other than regional) and foreign partners. The categories shown on the map are mutually exclusive.

On the basis of the obtained results, it can be concluded that international cooperation (shades of green) gains in strength with the growth of the total number of articles written in a given region. Podlaskie and Lubelskie demonstrate by far the greatest share of articles created solely with the participation of the regions' institutions, but in Śląskie, Łódzkie and Zachodniopomorskie the share of this category is also considerable (over 50%). Some voivodships, especially those with a small number of articles, strongly cooperate in this field with institutions from other voivodships, e.g. Świętokrzyskie, Lubuskie, Opolskie, and also Lubelskie. The directions of such cooperation are illustrated by Map 3.

The square size on Map 3 indicates the number of articles created in cooperation with other voivodships, while the thickness of the lines visualises the number of co-written articles, but only those created in cooperation with other regions and/or in international cooperation were taken into account (colours yellow and dark green on Map 2).

Map 3. Directions and cooperation strength between voivodships in articles published in 2007 in journals comprised in the Web of Science database.



Source: study by A. Olechnicka i A. Płoszaj on the basis of the ISI Web of Science database.

It follows from Map 3 that Warsaw is the hub of the network of interrelations between the majority of all the voivodships. There are a few exceptions of regions where the closest cooperation partners are other than Mazowieckie Voivodship. This concerns particularly small voivodships and their cooperation with a stronger and geographically nearest science centre. For instance, Lubuskie Voivodship collaborates most intensively with Wielkopolskie, Opolskie – with Dolnośląskie, Podkarpackie – with Małopolskie, Śląskie, as intensively –

with Małopolskie, Mazowieckie and Dolnośląskie. Analysis of the interconnections between cities indicates, moreover, several regions which, mainly because of the policentricity of the science network, show a large share of cooperation between particular towns. This is typical of Silesian cities, of the relations between Bydgoszcz and Toruń and between Gdańsk and Gdynia.

5. Conclusion

Since the science sector has a major bearing on innovation in a region, it is vitally important to estimate the region's scientific potential. The study is an attempt to find alternative ways of determining the potential of Polish science, based on the outcome of parametric evaluation by MNiSW and on the Web of Science database of publications and citations. The conclusions from the analysis confirm the thesis that there exist in Polish science strong regional discrepancies. The analysis also proved that Polish science institutions cooperate with one another in writing scientific articles and that Warsaw is the focal point of the network of interconnections between Polish science units. In some regions, however, other, less distant, science centres fulfil the role of benchmarks.

This study is merely a starting point for further research. The following questions delineate the direction of future analyses: 1) How long-lasting are the discrepancies in the potential of Polish science? 2) What factors ensure change in this area? What role is played by institutional factors, e.g. Poland joining the EU and globalization? 3) What is the potential of Polish science in particular fields? 4) How are the geography and the strength of links between scientific centres changing? 5) What role is played in building the potential of Polish science by enterprises? (demand for science outputs, inspiration, common projects).

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