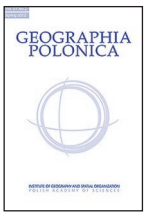

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RELATIONS OF GEOGRAPHY WITH OTHER DISCIPLINES: A BIBLIOMETRIC ANALYSIS

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Abstract

The aim of this article was to examine the relations of physical and human geography with selected disciplines of natural and exact sciences as well as social sciences. The results shows that: (1) the position of geography among other disciplines is relatively high, however the relative position of human geography in social sciences is higher than that of physical geography in natural and exact sciences, (2) both geographical disciplines show an adverse 'trade balance' in scientific exchange, (3) human geography is more 'introverted', (4) relations between human geography and other disciplines are stronger than in the case of physical geography.

Key words

geography • bibliometric analysis • journals • citations

Introduction

Relations of geography with other disciplines are often used to assess the operation of geography as an independent science (Turner 2002; Mulligan 2003; Lisowski 2004). Some researchers stress the weakness of geography resulting, among other things, from borrowing scientific knowledge from other fields (e.g. Mulligan 2003; Lisowski 2004). Others, in turn, claim that the weakness of geography is rather a result of its insufficient integration with other disciplines and reliance primarily on its own output (Ferguson 2003). Often, especially in Polish geography, the problem discussed is that of its poor internal integration, i.e. cooperation between physical and human geography, and the low position of geography in the science system and in practice (Lisowski 2008, 2011; Maik 2008; Richling 2008; Bański 2010, 2013).

The quantitative analyses of relations of geography with other disciplines made so far have focused primarily on Anglo-Saxon geography and involved comparing publication practices of physical and human geographers. With reference to young scholars, Thrift

(2002) reports that human geographers publish almost exclusively in journals representing their subdiscipline. The differences in the publication practices of researchers representing the two subdisciplines of geography were later corroborated by Ferguson (2003) and Johnston (2005). When examining publication practices of physical and human geographers, Ferguson (2003) analysed in what journals selected eminent scholars published their most influential works (with more than 20 citations in the Web of Science database). He found that physical geographers tended to publish in interdisciplinary journals decidedly more frequently than human geographers. This was confirmed by Johnston's (2005) study of British geography. On the basis of information given by geographical units for a parametric assessment of their scientific activity in 2001 (the so-called RAE, or Research Assessment Exercise), he showed that British human geographers published primarily in British geographical journals, while British physical geographers did so mainly in American interdisciplinary journals. Ferguson's (2003) and Johnston's (2005) results can provide a basis for the thesis that physical geography is more closely connected with natural sciences than human geography is with social sciences (Lisowski 2011), which can imply that physical geography occupies a higher position in the system of sciences. It should be kept in mind, however, that this situation may change in successive years. This is suggested by the results of a study by Foster et al. (2007), who demonstrated a growing share of important (i.e. highly cited) works by economic geographers in non-geographical journals after 1980.

Differences in publication practices between physical and human geographers are not limited to publication in different kinds of journals, but also involve a broader problem: the share of various scientific communication media. Ferguson (2003) explains the greater number of highly cited works in the output of eminent physical geographers, among other things, by the lesser significance of monographs in physical geography than in human geography, for which they are the chief medium for reporting the results of scholarly work in some countries (e.g. Ward et al. 2009; Bajerski & Siwek 2011).

These studies of publication practices of geographers, although valuable in cognitive terms, show the links of geography with other sciences only in an indirect way. In fact, they concern modes of scientific communication. However, relations among disciplines manifest themselves in the use of scientific knowledge and research methods (Chojnicki 1999: 93). Hence a direct picture of those relations can be obtained by analysing the use of geographical knowledge and methods in other disciplines and the use of knowledge and methods of other disciplines in geography. Such studies can be qualitative in nature, e.g. when the scope and significance of links is assessed on the basis of selected cases, or quantitative, when an analysis is made of the citation rates of works. Especially wide possibilities are offered by a quantitative analysis of citations; it allows covering a large number of articles and journals while reducing the arbitrariness of decisions taken in the course of the research procedure.

In spite of the advantages of an analysis of citations in the assessment of the links of geography with other sciences, only a few authors have used this method so far. One of the first analyses of the problems at hand was presented by Whitehand (1985), who focused on whether works authored by the group of the most often cited geographers were cited primarily by geographers, or also by representatives of other disciplines (without their identification). His study showed a comparable proportion of citations from geography and other disciplines, with citations by geographers dominating in the earlier years of their scholarly careers, and citations by representatives of other disciplines, in their later years.

The use of publications from physical and human geography by other disciplines was examined in the next years by Bodman (1991). He analysed citation rates of works authored by a large group of geographers

working at universities in Great Britain, the United States, Canada and Australia, holding posts corresponding to those of a lecturer or assistant professor, and higher. His study showed human geography to be much more 'introvert' than physical geography. Social and economic geographers were almost twice as often cited in key geographical journals as physical geographers (39% and 20% of all citations, respectively), and almost half as often in key journals of other disciplines (15% and 30%, respectively). This higher 'introversion' of human geography revealed by Bodman (1991) has been corroborated by Foster et al. (2007) and Laffan (2010). Foster et al. (2007) showed that the most frequently cited articles in economic geography, almost without change from the 1980s to the start of the 21st century, were those quoted in geographical journals (ca. 50-55% of all citations). Less frequently geographers' works were cited in journals representing environmental sciences (ca. 30%), urban studies (ca. 17%), and economy (ca. 12%). The use of the results of economic geography works in sociology, political science and management (up to 5%) was marginal, although growing.

In turn, Laffan (2010), in what might be the fullest quantitative study of the relations of geography with other disciplines based on an analysis of citations from the Web of Science, demonstrated that the 'introversion' level of human geography was one of the highest in the set of the 34 scientific disciplines he analysed (5th place). He calculated that the 'introversion' of human geography was 3.2 times higher than of physical geography, and showed that both geographical subdisciplines were more strongly connected with other disciplines than with each other.

Since the question of links of geography with other disciplines is still poorly understood, this article offers a quantitative look at this problem which is an extension of Laffan's (2010) research. The chief goal was to examine the strength of links of physical and human geography with selected disciplines of exact and natural sciences on the one hand and with social sciences on the other. The measure of the links was the number of citations of articles from geographical journals in those representing other disciplines and vice versa. More specifically, the article sought: (1) to determine the position of geography among related disciplines, (2) to identify disciplines most strongly associated with geography by an exchange of scientific information, (3) to determine the relations of knowledge import/export between human geography, physical geography and other disciplines, and (4) to determine the average strength of the links of human and physical geography with exact and natural sciences as well as social sciences.

What should be kept in mind is that this article, like the research results mentioned above, refers to so-called international geography. International geography, referred to in the text simply as geography, is assumed to be this part of results that are published in journals indexed by Thomson Reuters in the Web of Science database (although the application of the term 'international' to geography understood in this way arouses justified criticism because of its being dominated by Anglo-American researchers, journals and theories – see, e.g., Minca 2000, Guttiérrez & López-Nieva 2001; Short et al. 2001; Yeung 2001; Aalbers 2004; Simonsen 2004; Timár 2004; Aalbers & Rossi 2006, 2009; Bański & Ferenc 2013). The authors of this article are aware that in fact international geography is a resultant of diverse publication practices of scholars from a variety of regions and countries, which should also be a subject of separate studies (Schuermans et al. 2010; Bajerski 2011; Bajerski & Siwek 2012).

Chief sources of information about citations

In this study the relations of geography with other sciences were examined by analysing citations of articles published in geographical journals and those representing other disciplines science. At the initial stage of the research procedure an assessment was made

of possibilities offered by three citation bases most popular today: Web of Science, Scopus and Google Scholar[1]. Their individual characteristics, advantages and defects as well as the comparability of the results obtained have often been discussed in scientific literature (Bar-Ilan 2008; Vieira & Gomes 2009; Franceschet 2010; Mikki 2010; Mingers & Lipitakis 2010). Those three citation bases have also been used in earlier studies concerning Polish geography. Racki (2003) and Bajerski (2008b) relied on the Web of Science database, Bajerski (2008a) used the Scopus database, while Śleszyński (2009, 2013a, 2013b, 2014) resorted to the Google Scholar database.

The only citation database among those employed that allows an analysis of citations among disciplines is the Web of Science (cf. Tab. 1). In the Scopus database, journals are assigned to very generally defined fields of science (e.g. social sciences and the humanities, natural sciences), while Google Scholar does not make such an analysis possible at all. That is why in the research use was made of the Web of Science database.

The Web of Science is the oldest and most prestigious multi-field scientific citation database in the world. In 2011 it had more than 46 million indexed articles representing all fields of science. It had seven citation bases:

1. the Science Citation Index Expanded (SCIE), which indexes over 8.3 thous. journals from exact, natural and technical sciences, the oldest articles coming from 1900;
2 the Social Sciences Citation Index (SSCI), which indexes over 4.5 thous. journals from social sciences, the oldest articles coming from 1900;
3. the Arts & Humanities Citation Index (AHCI), which indexes over 2,3 thous. humanities journals, the oldest articles coming from 1975;
4. the Conference Proceedings Citation Index, which indexes conference materials from over 148 thous. conferences, including 12 thous. taking place every year; the oldest articles come from 1990;
5. Index Chemicus, which indexes articles from over 100 chemical journals and provides information about more than 2.6 chemical compounds; and
6. Current Chemical Reactions, which provides information about more than a million chemical reactions.
7. Book Citation Index, which indexes editorially selected books.

The most relevant for bibliometric purposes are the first three bases, i.e. the Science Citation Index Expanded (SCIE), the Social Sciences Citation Index (SSCI), and the Arts & Humanities Citation Index (AHCI). Together they provide information about more than 47 million scientific articles published in over 12 thous. journals. It should be kept in mind that this number is smaller than the sum of journals indexed in each of the bases discussed, because often a journal is indexed in two, and even all three of them. This holds, e.g., for general geographical journals publishing articles from both, natural and social sciences. The Web of Science database rests on a selected set of scientific journals embracing key periodicals in the given disciplines in the world. The decision to include a journal into one of those bases is preceded by a rigorous procedure in which such things are considered as punctual publication of its successive volumes, the international position of its authors and editorial board, and citation rates of articles published in it.

Most journals in the Web of Science database (ca. 65%, Tab. 1) come out in the United States, which leads to frequent criticism and accusations of 'Americentrism'. This at least a decade-long criticism of bases of the Web of Science and the Thomson Reuters corporation (Yitzhaki 1998; Archambault et al. 2006; Hassink 2007) has led to their opening to journals from regions and countries so far under-represented (e.g. Asia, South America, Africa, or East-Central Europe,

[1] Google Scholar indexes scientific articles like typical scientific databases, but in principle it is a freely accessible Web search engine.

Table 1. Basic information about the three most popular citation bases: Web of Science, Scopus and Google Scholar in 2011

Database characteristics	Web of Science	Scopus	Google Scholar
Type	database available on-line	database available on-line	internet search engine
Owner	Thompson Reuters	Elsevier	Google
Paid subscription	yes	yes	no
Launching year	1960 (Science Citation Index Expanded)	2002	2004
Number of indexed journals	ca. 12,000	ca. 18,000	not revealed by Google
Number of indexed articles	47 million	40 million	not revealed by Google
Possibility of full analysis of citations	1945 onwards	1996 onwards	n/a
Selectivity of journals	high	average	low
% of journals published in USA	ca. 65%	ca. 45%	n/a
Journals assigned to fields of science (e.g. social sciences)	yes	yes	no
Journals assigned to disciplines of science (e.g. geography)	yes	no	no

Source: own compilation on the basis of the Web of Science, Scopus and Google Scholar bases.

including Poland). As a result, a sudden jump can be observed, especially since 2007, in the number of journals published in some countries, like Poland, Lithuania or Turkey. On the one hand, this has made the Web of Science database more representative of world science, and on the other, apart from strictly international periodicals, it now includes also those that are regional or local in range.

Each journal indexed in the Web of Science can be assigned to one or several disciplines (Tab. 2). Nearly 60% of journals are assigned to only one discipline, and 30% to two. The most multidisciplinary journals are entered in six disciplines at once. Journals from natural and exact sciences represent a few disciplines slightly more often than those from social sciences.

Table 2. Journals by the number of fields to which they are assigned in the Web of Science database

Number of disciplines journal is assigned to	Natural and exact sciences (SCIE database)		Social sciences (SSCI database)		Total	
	number of journals	%	number of journals	%	number of journals	%
1	4,234	57.3	1,513	67.0	5,747	59.6
2	2,271	30.7	648	28.7	2,919	30.3
3	702	9.5	85	3.8	787	8.2
4	152	2.1	10	0.4	162	1.7
5	21	0.3	1	0.0	22	0.2
6	7	0.1	0	0.0	7	0.1
Total	7,387	100.0	2,257	100.0	9,644	100.0

Note: The table lists journals with an established impact factor, hence the total number of journals in the table is smaller than the sum of all journals indexed in the Web of Science database.

Source: own compilation on the basis of the Web of Science and Journal Citation Report (2009).

Research method

Formulation of assumptions and operational definitions

The basic assumption adopted in this study is that relations among disciplines can be established with the help of an analysis of citations. A citation is understood as an article from discipline A referring to a work from discipline B. It was assumed that a citation meant the use of knowledge resources of a given discipline, irrespective of whether the reference was favourable or critical. Hence the basic index of the relation among disciplines is the number of articles that do the citing. This relation can be bi-directional, i.e. while being an object of influence itself, a scientific discipline also influences other disciplines. Hence the examination of links between geography and other disciplines also involved an analysis of citations by geography of works from other disciplines and an analysis of citations of geographical works by other disciplines.

Geography occupies a specific position in the system of sciences since it examines both, natural and social phenomena; hence the basic division of geography into physical and human. And those two disciplines were the core of the analysis: physical geography, which belongs to natural and exact sciences in the Web of Science database, and human geography, included among social sciences there. The period under study was the years 2006-2010, i.e. the analysis embraced works published then. The data were collected in the winter of 2012 and the analysis was made in the spring and summer of 2013.

Choice of the disciplines examined

Although the conception of a scientific discipline has its methodological model (Chojnicki 1999: 83-96), in this study a practical understanding of this term was adopted as a category distinguished in the Web of Science database. In 2009 the classification created for this database embraced 173 disciplines of natural and exact sciences and 55 disciplines of social sciences (so called *Web of Sciences categories*). While the classification and the names given to the disciplines may raise some objections, it should be observed that in the contemporary debate on science – in the situation of deep specialisation and intertwining fields of many disciplines – it has in fact a practical character. This is pointed out by philosophers of science who, like Bunge (1998: 27), claim that today "it would be foolish to place much emphasis on the problem of classifying the sciences, once a favourite pastime of philosophers and now a subject for science administrators and librarians". This is also the practical character of the classification adopted in the Web of Science database; it could be a subject of a separate study, hence it is not discussed in this article.

The choice of concrete disciplines was dictated by several reasons. First, the disciplines taken into consideration were primarily those with years-long history. They were also usually represented by the largest number of journals on the Web of Science. Secondly, the selection was also based on a previous research on the topic (e.g. Foster et al. 2007; Laffan 2010). As a result, data were obtained for the two fields of geography as well as for 26 other categories (13 from natural and exact sciences and 13 from social sciences) that either share journals or are expected to have some citation relationship with geography. Out of the natural and exact sciences, those selected for study included the following categories: astronomy and astrophysics, biology, chemistry, ecology, physics, geochemistry and geophysics, geology, soil science, informatics, mathematics, oceanography, palaeontology, and remote sensing. From the group of social sciences, the disciplines chosen were: demography, economy, history, management science, political sciences, pedagogy, planning, psychology, sociology, international relations, regional studies, transport, tourism and recreation. In the case of human geography, we used the JCR category called Geography, and for physical geography we used the 'Geography, physical' category.

It is worth noting that although we used JCR categories as a substitute for disciplines, those two are not exactly the same. The allocation of journals to JCR categories is a heuristic process, as Pudovkin and Garfield (2002) explain. They note that "once the categories were established, new journals were assigned one at a time. Each decision was based upon a visual examination of all relevant citation data. As categories grew, subdivisions were established. Among other tools used to make individual journal assignments, the Hayne--Coulson algorithm is used. The algorithm has never been published. It treats any designated group of journals as one macrojournal and produces a combined printout of cited and citing journal data" (Pudovkin & Garfield 2002: 1113). It means that there is some subjectivity in the allocation of journals to the categories. This is a possible problem for the present analysis in that the categories may not truly represent the diversity of the discipline of geography. However, as Laffan (2010: 168) points out, "the categories do appear to be logical groupings, journals can be indexed in more than one category, and the data do allow broad differences and relationships to be assessed".

Choice of the research method

Because of the assumption that relations among disciplines can be established through an analysis of citations, use was made of bibliometric methods, in particular of Pudovkin's index, known in bibliometrics and worked out in the 1990s. Detailed information and examples of its use can be found in Pudovkin (1993), Pudovkin and Fuseler (1995), and Pudovkin and Garfield (2002). This index is given by the formula:

$$R_{AB} = CIT_{AB} / (CIT_A * ART_B) * 10^7$$

where:

R_{AB} – strength of the relation between disciplines A and B,

CIT_{AB} – number of articles citing works from discipline A in articles from discipline B,

CIT_A – number of articles citing articles from discipline A,

ART_B – number of published articles from discipline B.

The index assumes values from zero to infinity and is measured on a quotient scale, which makes the relations among its values reliable. It is relative in nature, i.e. the strength of a relation should be assessed by reference to other relations or to mean values. Its advantage is that it gives the number of citations between two disciplines examined in relation to the total citation count of a discipline. Also, it offers not only the absolute citation count, but also the volume of the scientific production of this discipline understood as the number of articles published by journals belonging to it. To illustrate the complex relations among disciplines, let us give the following example. In the years 2006-2010 human geography cited 573 articles from economy, and economy, 937 articles from human geography[2] (cf. Tab. 4). This might imply that it was geography that supplied more knowledge to economy than the other way round. However, there were 37,187 articles published in economy over this time as against 9,552 of those in human geography. This means that, in a relative approach, 5.7% of geographical articles cited economy, and a mere 2.5% of economic articles cited geography. In turn, all geographical articles were cited by a total of 5,497 works, and economic papers by 19,659 articles. Hence the relation of the citations of geographical works by economy to all citations of geographical works is 0.10 (573/5,497), and the proportion of citations of economic works by human geography to all citations of economic works is 0.05 (937/19,659). It is

[2] It should be kept in mind that formulations like 'human geography cited economy' are stylistic phrases intended to make the text more readable. What is meant here are articles in journals classified as belonging to the 'human geography' field in the Web of Science database whose authors cite works from journals belonging to the 'economy' field in this database. This remark also applies to the later text where this type of phrases appear as well.

important to take into consideration those various aspects of the bi-directional relations between disciplines, and Pudovkin's index helps to model the complex links among disciplines in a simple way. For the geography-economy relation, this index amounts to 23.0, and for the economy-geography relation, 19.7. This means a slightly stronger relation of geography with economy than of economy with geography. This can be interpreted in terms of an exchange of goods in trade: human geography 'imports' a bit more goods from economy than it 'exports' to it. In Pudovkin's index the multiplier 10^7 is established arbitrarily, its task being only to make the interpretation of results easier, because index values are very low. Thus, instead of 0.00000155 we get 15.5. This has no influence whatsoever on the variability of values or the results of analyses.

In the study use was also made of the impact factor of journals, which presents the frequency with which articles from a journal are cited over a specified time. In fact, this is an index of the general prestige and force of influence of scientific journals. It is calculated by the Institute for Scientific Information in Philadelphia as a simple quotient of two quantities:

$$IF = X/Y,$$

where:

- X – is the total number of citations of all publications a journal received in a given calendar year that appeared in it over two the years preceding that year (without self-citations), and
- Y – is the number of all publications that appeared in that period. For example, if the index was 3 in 2010, this means that each publication that appeared in the journal in the years 2008-2009 was cited 3 times on average in 2010 by the authors of other publications in journals listed by the Institute for Scientific Information in Philadelphia. This index can assume values from zero to infinity, but in practice maximum values are ca. 30 for the most prestigious journals.

Collecting and processing the data and their analysis

The next stage involved collecting and processing data. As has already been mentioned, all information concerning citations comes from the Web of Science database. Citation counts were made for a total of 632,582 articles from 28 fields (2 geographical disciplines and 26 associated ones) and the material was further analysed using the methods described above. The basic part of the research procedure was an analysis of relations of the two geographical disciplines with other disciplines, the results of which are presented in a later part of this paper.

Geography and other scientific disciplines

The chief goals sought in the analysis of links of geography with other disciplines included: (a) establishing the position of geography among the disciplines examined, (b) defining the set of disciplines making most frequent use of geographical knowledge and the intensity of this use, (c) defining the set of disciplines from which geography derives knowledge and the intensity of this use, and (d) determining the strength of the relation between geography and the other disciplines.

The position of geography measured by the impact factor of scientific journals was relatively high (Tab. 3). Human geography came fourth among the 14 disciplines of social sciences examined, with the impact factor of 1.37, higher than for economy and sociology. In turn, physical geography occupied sixth position among the 14 disciplines of natural and exact sciences examined, with the impact factor of 2.29, higher than, e.g., in geology and palaeontology. It should be noted that an average article in physical geography had almost one citation more than an average article in human geography. In terms of the number of journals and published articles, geography came as a medium-sized discipline. In social sciences the biggest disciplines were economy, management

science and political science, and in natural and exact sciences, physics, ecology and chemistry.

Because the position of the geographical disciplines with respect to the selected disciplines presented above could not match the actual position of geography, its place was checked relative to all disciplines entered in the Web of Science database. In terms of the impact factor, in 2009 human geography occupied 20th place among 55 disciplines of social sciences, and physical geography, 79th place among 173 disciplines of natural and exact sciences. Because the number of disciplines varies in natural and exact sciences, in order to compare the relative positions of the two disciplines their positions were normalised in the ranking (within the range of 0 to 100). This put human geography in the middle of the third decile (36th

Table 3. The position of geography among the examined disciplines in 2009

(a) Physical geography among the examined disciplines of natural sciences

No.	Discipline	Impact factor average	Number of journals	Number of articles
1.	Astronomy and astrophysics	4.44	53	14,562
2.	Biology	3.08	76	11,427
3.	Physics	2.89	71	21,998
4.	Ecology	2.78	129	14,289
5.	Chemistry	2.64	70	17,687
6.	**Physical geography**	**2.29**	**36**	**3,420**
7.	Geochemistry and geophysics	2.15	75	7,687
8.	Oceanography	1.90	56	4,950
9.	Remote sensing	1.73	21	1,934
10.	Geology	1.72	49	2,167
11.	Soil science	1.70	31	3,515
12.	Palaeontology	1.68	41	2,125
13.	Informatics	1.65	95	9,576
14.	Mathematics	1.55	80	6,737

(b) Human geography among the examined disciplines of social sciences

No.	Discipline	Impact factor average	Number of journals	Number of articles
1.	Psychology	1.68	50	2,813
2.	Management science	1.65	112	4,932
3.	Transport	1.44	18	873
4.	**Human geography**	**1.37**	**62**	**2,334**
5.	Tourism and recreation	1.28	20	703
6.	Economy	1.15	247	11,856
7.	Demography	1.14	24	686
8.	Planning and development	1.05	44	1,860
9.	Sociology	0.92	114	3,581
10.	Pedagogy	0.88	139	5,339
11.	International relations	0.86	59	2,026
12.	Political science	0.81	112	4,259
13.	Regional studies	0.54	44	1,275
14.	History	0.36	32	726

Source: own compilation on the basis of Journal Citation Report 2009.

place), and physical geography, in the middle of the fourth decile (46th place). This shows the relative position of human geography among social sciences to be slightly higher than that of physical geography among natural and exact sciences.

One of the major aspects of relations of geography with other disciplines is determining the set of disciplines making most frequent use of geographical knowledge and the intensity of this use. This is done via an analysis of citations of works published in journals classed as geographical. For all articles in geography published in the years 2006--2010, the number of articles citing them was examined and the disciplines they belonged to were identified. The results are presented in Tables 4a and 5a. Works from physical geography were referred to by 13.5 thous. articles, and those from human geography were cited by 5.6 thous. articles. Slightly more than a half of works (54.0%) citing physical geography came from three disciplines: ecology, physical geography and palaeontology. In human geography, a similar proportion of articles (52.8%) were cited by four disciplines: human geography, ecology, economy, and planning. In the case of physical geography there was a greater 'concentration' of citations: the ten most frequently citing disciplines made up 95.0% of all citations, while in human geography they accounted for 80.7% of citations.

The next aspect of relations of geography with other disciplines was determining the set of disciplines from which geography derives knowledge. As in the case of the use of geographical knowledge, this was done *via* an analysis of citations of works published in journals classed as belonging to the various scientific disciplines. For all works from the 28 disciplines selected, published in the years 2006-2010, the number of articles cited by geographical works was examined. The results are presented in Tables 4b and 5b. Physical geography most frequently cited works from ecology, physical geography, geology, as well as geochemistry and geophysics; works in those disciplines accounted for 66.5% of all articles cited. Human geography most frequently cited itself as well as works from economy, planning, and sociology, which together made up 60.2% of the articles cited. The set of those disciplines was similar to the one that cited geographical works most often. This means that each of the two geographical disciplines has a core of disciplines from which it draws knowledge, but also which reciprocate and make use of geographical knowledge. The only discipline strongly

Table 4. Disciplines making use of the knowledge of human geography

(a) Disciplines most often citing human geography

No.	Discipline	Articles citing	
		number	%
1.	Human geography	1,196	21.2
2.	Ecology	667	11.8
3.	Economy	573	10.2
4.	Planning	534	9.5
5.	Physical geography	407	7.2
6.	Sociology	347	6.2
7.	Management science	231	4.1
8.	Political science	231	4.1
9.	Transport	202	3.6
10.	Remote sensing	156	2.8
	Remaining 18 disciplines	1,085	19.3
	Total	5,629	100.0

(b) Disciplines most often cited by human geography

Lp.	Discipline	Articles cited	
		number	%
1.	Human geography	1,196	16.7
2.	Economy	937	13.1
3.	Planning	772	10.8
4.	Ecology	755	10.6
5.	Sociology	647	9.0
6.	Political science	477	6.7
7.	Physical geography	467	6.5
8.	Management science	273	3.8
9.	International relations	209	2.9
10.	Remote sensing	182	2.5
	Remaining 18 disciplines	1,240	17.3
	Total	7,155	100.0

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

connected with both physical and human geography was ecology. This is not surprising if we consider that ecology studies, among other things, relations holding between man and the environment, and those are some of the basic elements of modern research problems in geography (Chojnicki 2000; Maik 2004, 2008).

Also characteristic are relations between the two geographical disciplines, which make use of each other's output, but this relation is asymmetric. Human geography refers to works in physical geography more often than the other way round. About 7% of works cited by or citing human geography belonged to physical geography, while ca. 3% of works cited by or citing physical geography belonged to human geography. There seems to be a tendency for human geography to cite works from natural and exact sciences generally more often than physical geography cites works from social sciences. In human geography, 27.0% of the articles it cited represented natural and exact sciences, while 5.9% of physical geography papers referred to works from social sciences. Even if we exclude works from ecology and physical geography, works from natural and exact sciences still accounted for 9.9% of all those cited by human geography. This group included remote sensing (2.5% of the works cited), geology (1.4%), informatics (1.3%), mathematics (1.3%), and soil science (1.0%). The social science disciplines most frequently cited by physical geography included economy (0.7% of the works cited), planning (0.6%), and sociology (0.5%).

To determine the intensity and complexity of links between geography and the other disciplines, use was made of Pudovkin's index characterised in the section of the article describing the research methodology. This index was used to examine bi-directional relations between the two geographical disciplines and the remaining ones, termed the strength of the relation. The bi-directionality of relations means the use of knowledge from discipline A by discipline B and the use of knowledge from disciplines B by discipline A. On this basis it is possible to determine the 'trade balance' of scientific knowledge, hence in the interpretation of the results obtained use was made of terms connected with economic trade, like import and export, and trade surplus or deficit. For example, 'import' in the relations of physical geography with geology means the use of geological knowledge by geography (as expressed

Table 5. Disciplines drawing on knowledge from physical geography

(a) Disciplines most frequently citing physical geography

No.	Discipline	Articles citing	
		number	%
1.	Ecology	4,133	30.7
2.	Physical geography	1,855	13.8
3.	Palaeontology	1,281	9.5
4.	Geochemistry and geophysics	1,262	9.4
5.	Geology	1,104	8.2
6.	Oceanography	948	7.0
7.	Remote sensing	861	6.4
8.	Human geography	467	3.5
9.	Biology	446	3.3
10.	Soil science	446	3.3
	Remaining 18 disciplines	667	5.0
	Total	13,470	100.0

(b) Disciplines most often cited by physical geography

No.	Discipline	Articles cited	
		number	%
1.	Ecology	3,482	27.3
2.	Physical geography	1,855	14.5
3.	Geology	1,641	12.9
4.	Geochemistry and geophysics	1,505	11.8
5.	Palaeontology	919	7.2
6.	Oceanography	829	6.5
7.	Remote sensing	595	4.7
8.	Soil science	478	3.7
9.	Biology	427	3.3
10.	Human geography	407	3.2
	Remaining 18 disciplines	615	4.8
	Total	12,753	100.0

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

by relatively frequent citations of geological works in geographical articles, taking into consideration the size of the disciplines), while 'export' means the use of geographical knowledge by geology (as expressed by relative citation rates of geographical works in geological articles, taking into consideration the size of the disciplines). A favourable 'trade balance' means that 'exports' dominate over 'imports', i.e. that geology takes greater advantage of geographical knowledge than physical geography of geological knowledge. And the other way round, an adverse 'trade balance' means the dominance of 'imports' over 'exports', i.e. that physical geography derives more knowledge from geology than geology from geography.

In the analysis, values of the index of the strength of the relation of geography with other disciplines under 10 were taken to be low, between 10 and 30, average, and over 30, high. It should be stressed that establishing a uniform interpretation is fairly difficult because of differences between the geographical disciplines. In physical geography the average strength of the relation was 15.5 (the median 2.5; standard deviation 25.6), in human geography, 25.7 (the median 11.7; standard deviation 36.8), and for the whole of geography, 20.6 (the median 5.1; standard deviation 31.9). Readily visible are differences in the values for the individual disciplines.

The relations of human geography with other disciplines are presented in Figure 1. It shows them to be the strongest with social sciences, especially with planning, regional studies and demography, although there are disciplines in natural and exact sciences with which this relation is also strong (e.g. with physical geography and remote sensing). Predominant in the relations with social sciences are 'deficits' in the scientific 'trade balance', which means that human geography makes more frequent use of the output of other

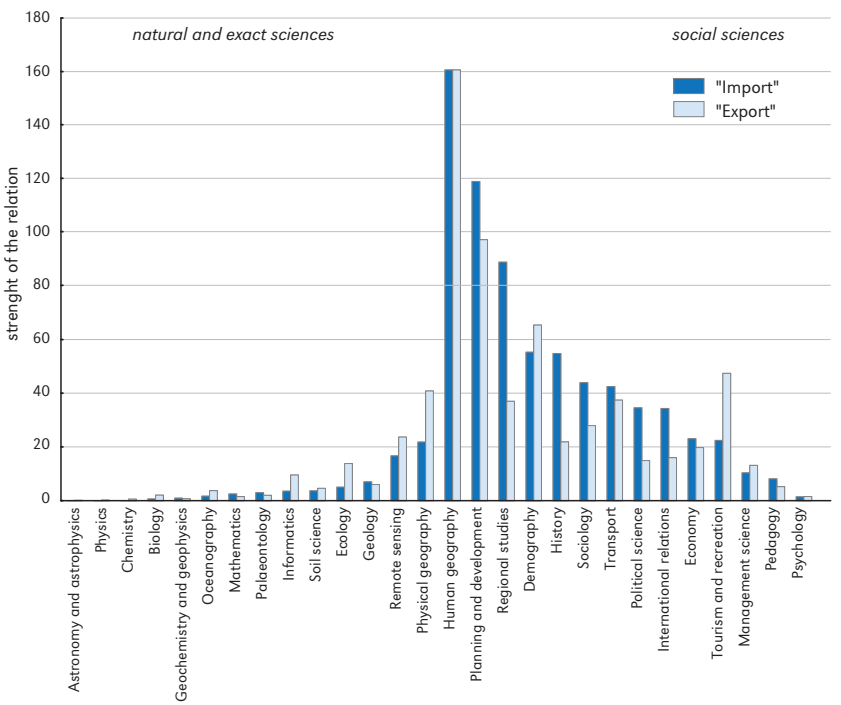

Figure 1. Relations of human geography with other disciplines

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

sciences than the other way round. The disciplines with which human geography has the most adverse 'trade balance' include regional studies, history and planning, and the most favourable 'trade balance', with tourism and recreation, ecology, and physical geography, of which the last two are classed as natural and exact sciences.

Relations of physical geography with other disciplines are presented in Figure 2. As in the case of human geography, there is a predominance of 'deficits' on its scientific trade, which means that physical geography makes more frequent use of the output of the other sciences. The disciplines with which physical geography has the most adverse 'trade balance' include geology, palaeontology and human geography, while its most favourable 'trade balance' is with ecology, remote sensing, biology, and informatics.

The analysis conducted supplies some arguments in the discussion of the dichotomy of geography (e.g. Lisowski 1996; Maik 2004, 2008), because relations with other disciplines are in many cases stronger than between the geographical disciplines. The strength of the bi-directional relation of human geography with physical geography is 31.3, much weaker than its links with planning (108.0), regional studies (62.9), demography (60,3), transport sciences (39.9), history (38.3), sociology (36.0), and tourism and recreation (34.9). The situation is similar in the case of physical geography: its relations with palaeontology (94.9), geology (69.7) and remote sensing (45.5) are stronger than with human geography. Generally, the relations of human geography with social sciences are stronger than those of physical geography with natural and exact sciences, as Table 6 shows. The latter make more frequent use of the output of human geography than social sciences of the output of physical geography. The 'trade balance' in the relation between the two geographical disciplines is in favour of human geography, which means that it makes more frequent use of the output of physical geography than the other way round. Both geographies also rely on their own works, with the proportion of citations of a discipline's own works in the total number of the articles cited in it being higher in human geography (15.3%) than in physical geography (8.7%). This means that geography

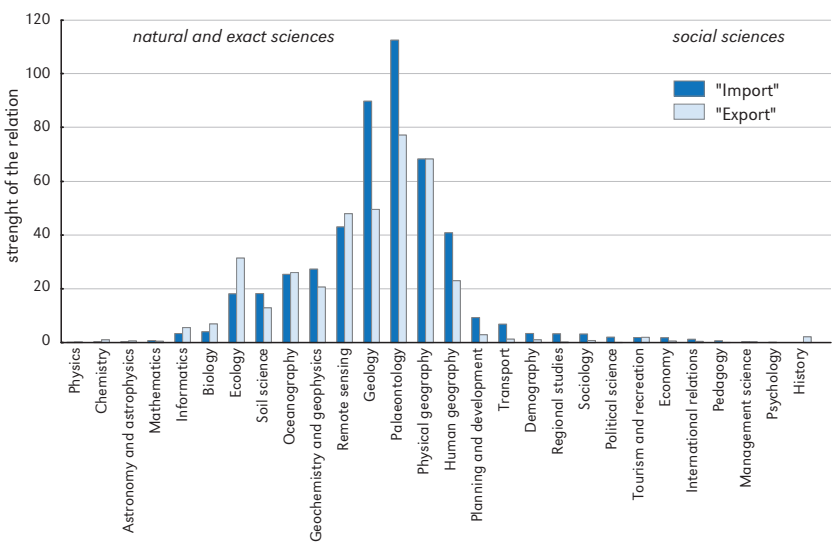

Figure 2. Relations of physical geography with other disciplines

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

Table 6. Average strength of the relation of geography with other disciplines (mean value of Pudovkin's index)

Group of disciplines	Physical geography		Human geography	
	'import'	'export'	'import'	'export
Natural and exact sciences	29.4	24.9	4.7	7.8
Natural and exact sciences (without physical geography)	26.4	21.6	3.4	5.2
Social sciences	5.3	2.4	49.9	40.4
Social sciences (without human geography)	2.6	0.9	41.4	31.1

Source: own compilation.

makes relatively little use of its own output. By comparison, in other disciplines such self-citation rates are: astronomy and astrophysics, 74.4%; economy, 52.4%; chemistry, 35.4%; ecology, 32.9%); pedagogy 32.5%; geochemistry, 30.0%; and history, 29.8%.

Summing up and conclusions

The conducted analysis of relations of geography with other disciplines can be summed up as follows:

1. The position of geography among other disciplines as measured by the impact factor of scientific journals is not as low as can be supposed. The relative position of human geography in social sciences is higher than that of physical geography in natural and exact sciences, although works of the latter are generally cited more often.

2. Both geographical disciplines show an adverse 'trade balance' in scientific exchange, which means that they make more frequent use of knowledge from other disciplines than the other way round.

3. Human geography is more 'introverted', which means that it cites its own works more often than physical geography. Even so, the use of a discipline's own works is low in geography as a whole when compared with other disciplines.

4. In human geography relations with other disciplines are stronger and link it with a greater number of disciplines than in the case of physical geography. Also, human geography draws on the output of natural and exact sciences more often than physical geography does on that of social sciences.

5. In internal relations physical geography 'imports' more from of human geography than it 'exports' to it.

The above conclusions largely corroborate those reached by Laffan (2010), who, using a similar research procedure, also showed that human geography and physical geography were characterised by an adverse 'trade balance' in scientific exchange, and that human geography displayed higher 'introversion'.

Finally, it is worth remembering that one should be careful in the interpretation of the results, for several reasons, of which two seem to be the most significant. First, the results of the analysis of the relations of geography with other sciences presented in this article, like the earlier empirical studies in this field, concern primarily world geography, which is dominated by American and British geographers. As those earlier works have shown, the proportion of authors from English-speaking countries in the journals indexed in the Web of Science database usually varies between 70% and 90% (e.g. Guttiérrez & López-Nieva 2001; Foster et al. 2007; Bański & Ferenc 2013). The situation of geography in Poland and other countries can differ from the one presented here, depending on the relations between individual disciplines specific to each national system of sciences that have formed over a long period of time.

Secondly, the analysis revealed that this type of research has to face some challenges.

Among them are different citation mechanisms operating in social and natural sciences, hence also in human geography and physical geography. In social sciences the diffusion of knowledge is slower than in natural ones. For example, in the case of articles from physics the first citations appear already a month or two after their publication, while for works in economy, sociology or human geography this period is a few years, with a citation peak sometimes a decade or several decades after the publication (Foster et al. 2007). Besides, our analysis rested on articles published in scientific journals and did not consider other modes of scholarly communication. But in social sciences monographs play a greater role in communicating research results than in natural sciences.

Irrespective of those challenges, it seems that this type of research can supply arguments in the discussion about the state and development of geography, also Polish geography. Especially so that one can observe discrepancies between objective indices and subjective assessments of the role and position of geography in the system of sciences. Hence it would be desirable to continue this type of analysis and improve methods of studying relations of geography with other disciplines, as well as those between the two geographical disciplines: physical and human.

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