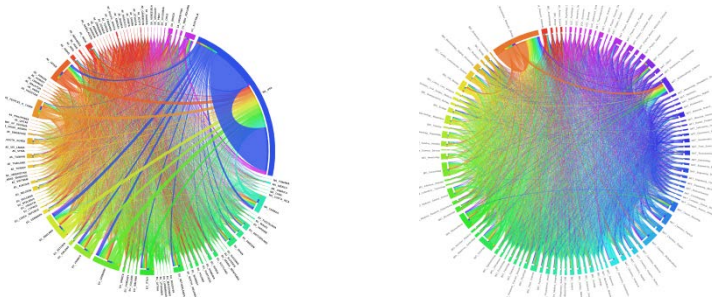
Graphical representations of international and interdisciplinary links in science

Steffen Hillmert[1]

University of Tübingen

2017

DOI: 10.17605/OSF.IO/37N9J



Abstract

Patterns of connectedness in science among national contexts and scientific disciplines are described in the form of illustrative diagrams. The analyses are based on large-scale citation data covering the historical period between 1985 and 2012. Global illustrations as well as some more differentiated trends are presented for both international and interdisciplinary links. Such graphical illustrations may not only help to better understand patterns of information exchange in science but also promote attention for the field of scientometrics.

[1] Department of Sociology, Wilhelmstr. 36, 72074 Tübingen, Germany. Email: steffen.hillmert@uni-tuebingen.de

Introduction

Science is dedicated to principles of universalism. This does not rule out considerable divisions within science, but these parts – in particular regional entities and disciplinary fields within science – are typically interdependent. There has therefore been a constant interest in the study of science to conduct not only topic-specific or author-specific analyses but also to produce *global* mappings of both differences and interrelations within science (Klavans and Boyack 2006). Collaboration, citation and mobility can be regarded as major means of exchange and connectedness and therefore main research topics for spatial scientometrics (Frenken et al. 2009). On the other hand, scientific discipline and national context are major dimensions for mapping differences and trends in science (Small and Garfield 1986). With regard to internal differentiation, diagnoses of a fundamental dualization in sciences (e.g., Snow 1959) neglect the high degree of specialization and heterogeneity within scientific fields and have proved to be too simple. However, given the multitude of detailed results that have been produced within the booming field of scientometrics in recent years, the need for more global and easily comprehensible accounts has probably increased rather than decreased.

To facilitate access to questions about differentiation and connectedness in science, the illustrations presented in this paper provide global snapshots of fundamental patterns of scientific exchange. The central indicators of these international and interdisciplinary links are mutual citations in scientific publications (Van Leuwen and Tijssen 2000).

Data

The data was collected in 2012 from the Thomson Reuters Web of Science© combined database containing information about the Science Citation Index (SCI), the Social Science Citation Index (SSCI), and the Arts and Humanities Citation Index (A&HCI).[2] This database is very comprehensive, and similar data has been successfully used for scientometric studies for many years such as analyses of national scientific production (e.g., Frame et al. 1977, King 2004); international collaboration (e.g., Luukkonen et al. 1993); interdisciplinarity (e.g., Morillo et al. 2003; Boyack et al. 2005; Moya-Anegóet al. 2007); and links among scientific journals (e.g., Leydesdorff and Schank 2008). Though the combined database is not limited to the natural sciences it is certainly dominated by sources from the natural sciences. After assessing the total size of the database, the first step of the data collection was the random selection of approximately 200.000 articles published between 1985 and 2012. In the next step, all papers that cited these articles were selected. This procedure ensured the availability of valid information on all citations (as the objects of citation are necessarily part of the database). It resulted in a total sample of approximately 2,360,000 papers that are the basis of the graphical illustrations. For these papers, selected information was retrieved including the national context (indicated by the address of the first author: 195 countries) and the (first) subject category of the respective journal (253 categories) as provided by the database. Not least to the volume and the complexity of the underlying data, techniques of visualization have always been prominent in the study of science (Börner et al. 2003; Börner and Scharnhorst 2009). They condense complex information and allow identifying basic structures in the data. For the design of circular graphs with *Circos* see Krzywinski et al. 2009.

[2] I would like to thank Michael Schweiker for his support with the data collection.

Global illustrations of international and interdisciplinary links

The following illustrations have been deliberately designed to provide an overall impression of the connectedness among national contexts and scientific fields. I therefore refrain at this point from a detailed analysis of the various categories. Figure 1 maps links between national scientific contexts. The figure shows the "flows" of active and passive citations among countries during the observation period. For a better comprehension the countries have been clustered by continent and ordered alphabetically within continents. The width of the connecting lines (at the starting point) is proportional to the number of citations received. Probably most obvious are the large proportion of the United States among all citations and the large flow of (self-)citations *within* the U.S. Besides manifest structures of scientific practice this is certainly also a reflection of the focus of the specific database. Figure 2 illustrates citation-based links among scientific disciplines. Again, the analysis presents a global description. Scientific (sub-)fields have been clustered into disciplinary sectors and ordered alphabetically within these clusters. Most striking is probably the large proportion of Biochemistry/Molecular Biology. This includes a large amount of self-citation but is not limited to that.

Figure 1: Citation links between national contexts

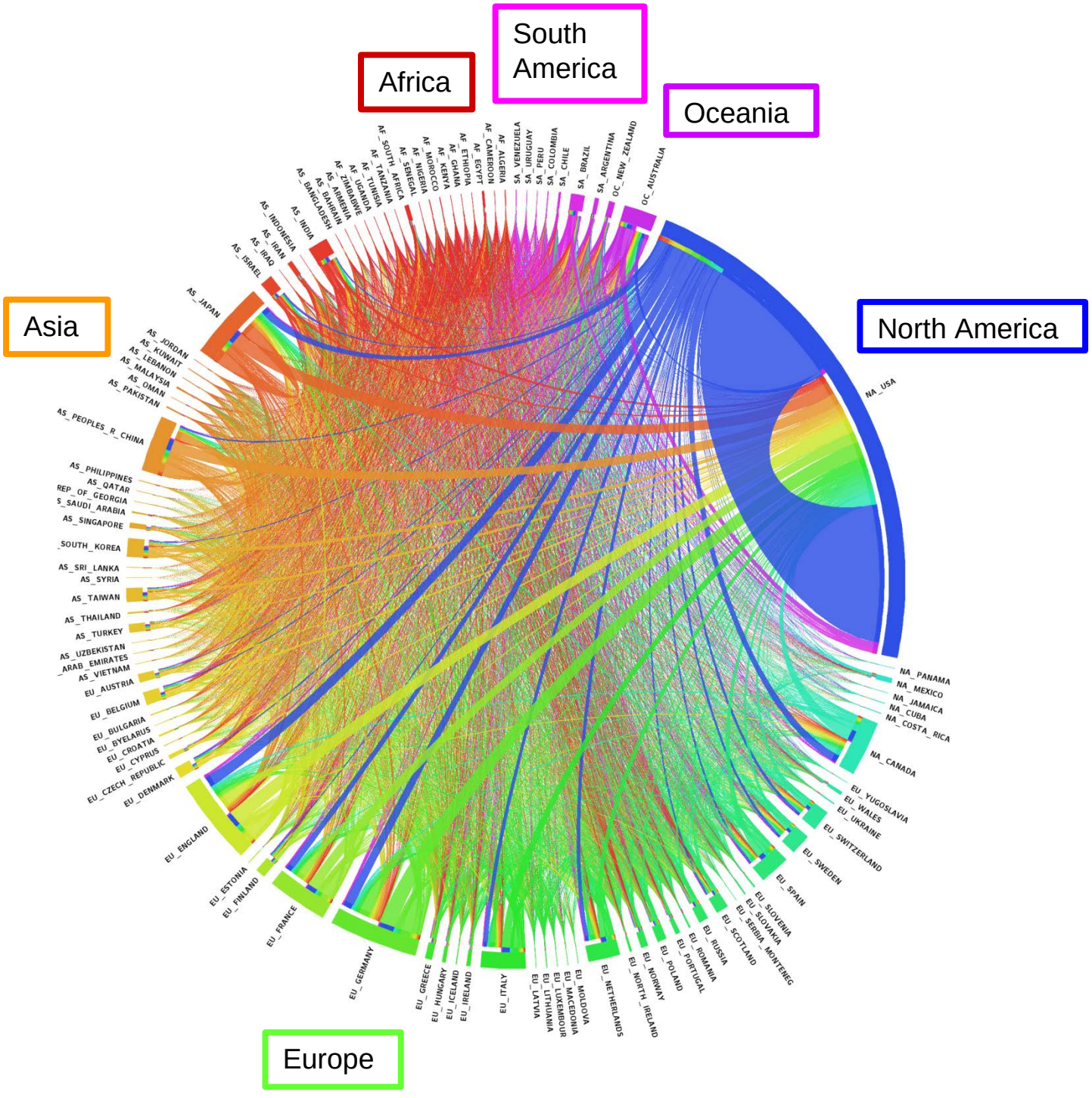
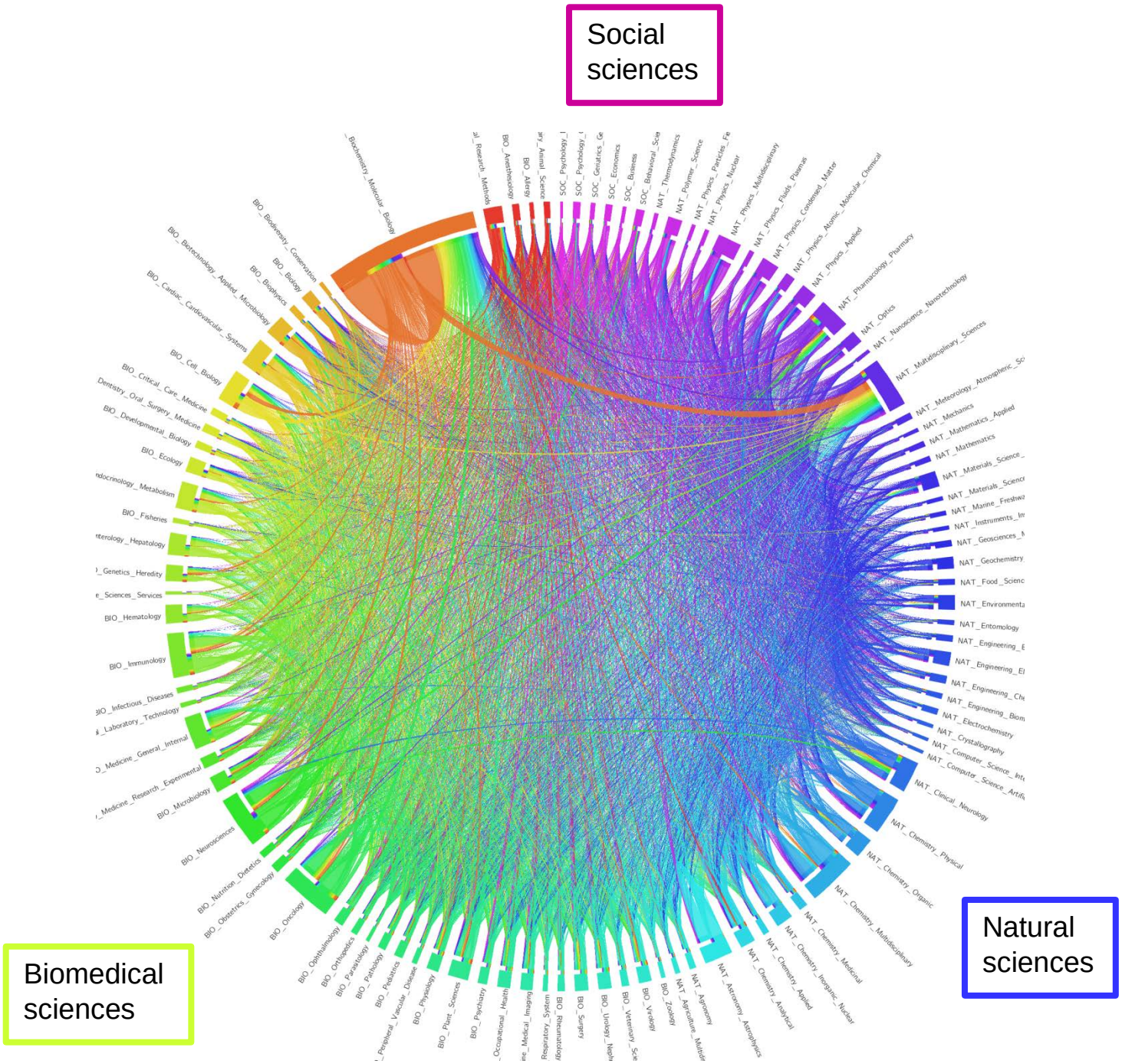


Figure 2: Citation links between disciplinary contexts

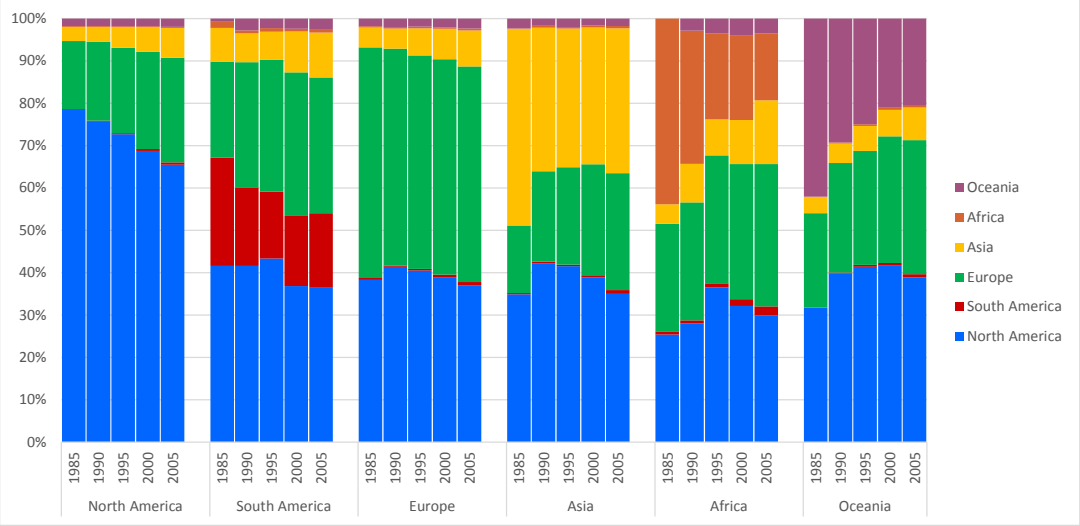


While these figures provide a comprehensive overview, it may be hard to identify systematic structures on that basis. The following figures therefore present higher aggregated findings. Figure 3 illustrates the citation links between (first) authors located on different continents. It also includes historical trends, comparing the situation among groups of five years (each of which starts with the year stated below the respective column). The first panel (a) represents the distributions of the locations of the authors that authors from a given continent (on the x axis) have cited. The second panel (b) represents the distributions of the locations of the authors that have cited authors from a given continent (on the x axis). As expected, citations within a particular continent have always had a prominent position. In North America, Europe and – with regard to passive citations – also Asia, intra-continental citations account for the majority of citations. These patterns have remained relatively stable over time. It should also be noted that the trends reflect both real-world developments and possible changes in the coverage of the database.

Figure 4 shows the links between authors from different disciplinary sectors. It also includes historical trends by comparing the situation among groups of five years. The first panel (a) represents the distributions of the disciplinary locations of the authors that authors from a given disciplinary background (on the x axis) have cited. The second panel (b) represents the distributions of the locations of the authors that have cited authors from a given disciplinary background (on the x axis). Sector-internal citations dominate the citations in all of the disciplinary sectors. These patterns have remained stable over time except for Arts and Humanities. However, the database for this particular sector is only small, and its coverage has developed rapidly over time.

Figure 3: Citation links between continents and their trends

(a) citing



(b) being cited

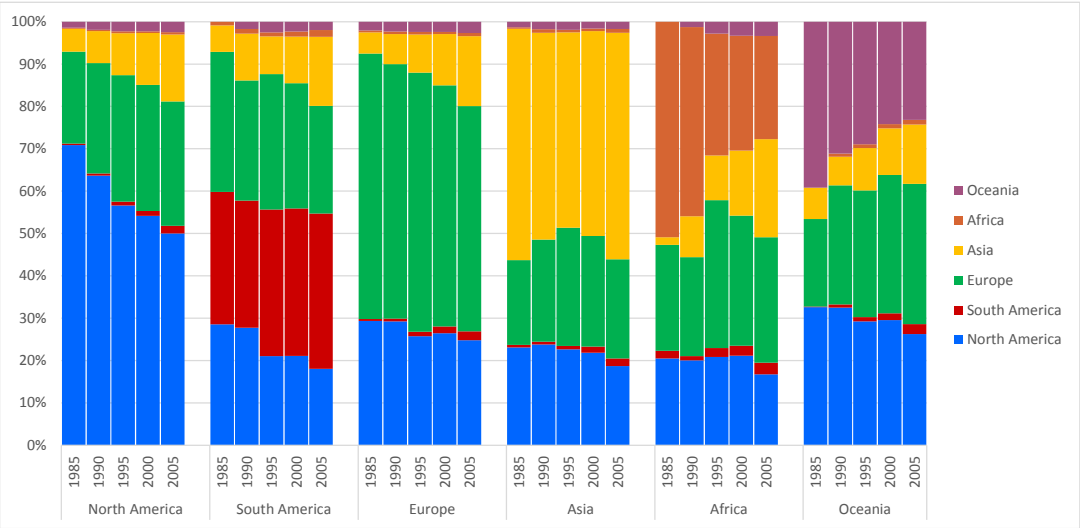
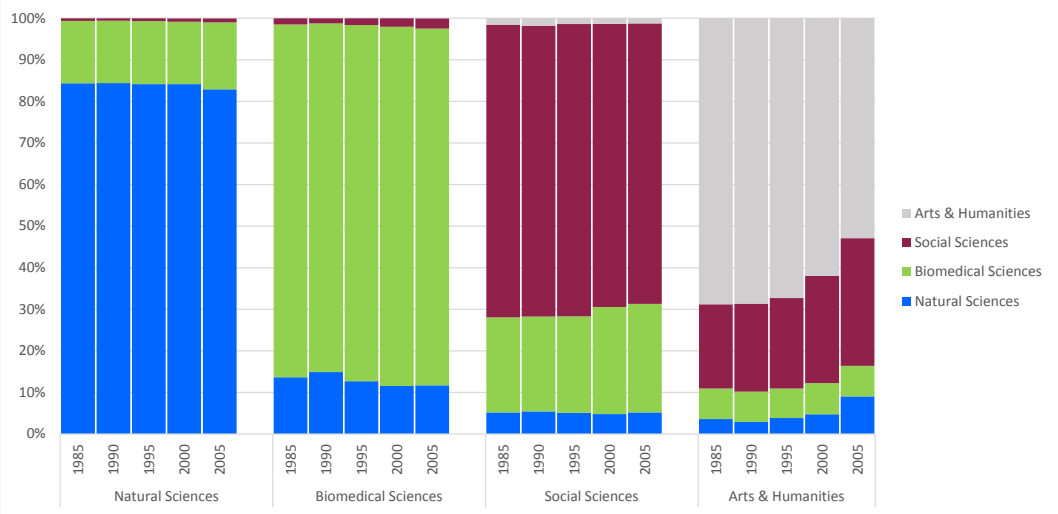
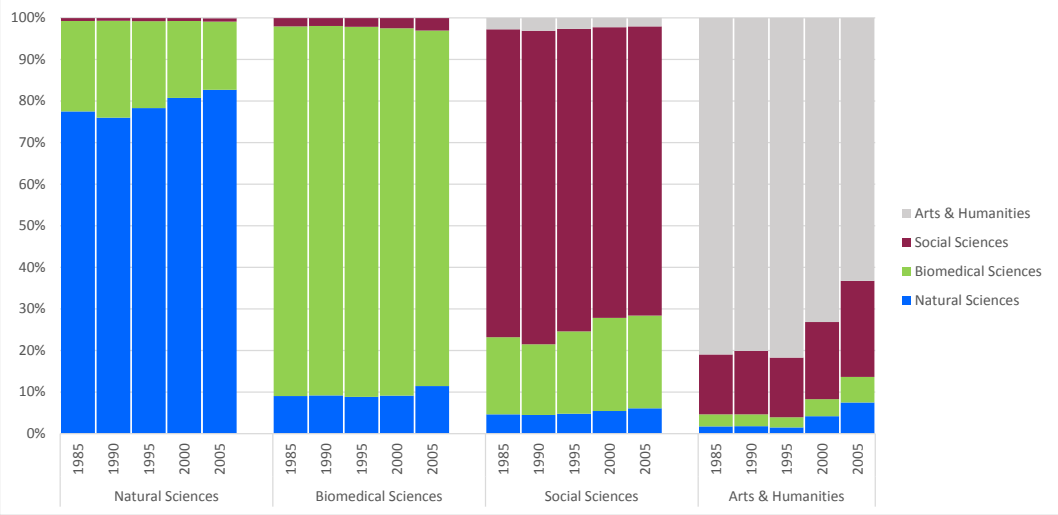


Figure 4: Citation links between disciplinary sectors and their trends

(a) citing



(b) being cited



Conclusion

In spite of considerable cross-cutting links, mutual attention and exchange within science are to a large extent structured by national and disciplinary boundaries. Many of these patterns have remained relatively stable over the last decades. Intuitive graphical illustrations may not only help to better understand these patterns of information exchange and their differentiation and developments but also promote attention for the field of scientometrics in general.

References

Börner, Katy, Chen, Chaomei and Boyack, Kevin W. (2003): Visualizing knowledge domains. *Annual Review of Information Science and Technology* 37: 179-255.

Börner, Katy and Scharnhorst, Andrea (2009): Visual conceptualizations and models of science. *Journal of Informetrics* 3: 161-172.

Boyack, Kevin W., Klavans, Richard and Börner, Katy (2005): Mapping the backbone of science. *Scientometrics* 64(3): 351-374.

Frame, J. Davidson, Narin, Francis and Carpenter, Mark P. (1977): The distribution of world science. *Social Studies of Science* 7: 501-516

Frenken, Koen, Hardemman, Sjoerd and Hoekman, Jarno (2009): Spatial scientometrics: Towards a cumulative research program. *Journal of Informetrics* 3: 222-232.

King, David A. (2004): The scientific impact of nations: What different countries get for their research spending. *Nature* 430: 311-316.

Klavans, Richard and Boyack, Kevin W. (2006): Quantitative evaluation of large maps of science. *Scientometrics* 68 (3): 475-499.

Krzywinski, Martin I., Jacqueline E. Schein, Inanc Birol, Joseph Connors, Randy Gascoyne, Doug Horsman, Steven J. Jones, and Marco A Marra (2009): Circos: An information aesthetic for comparative genomics. *Genome Research,* 19: 1639-1645.

Leydesdorff, Loet and Schank, Thomas (2008): Dynamic animations of journal maps: indicators of structural changes and interdisciplinary developments. *Journal of the American Society for Information Science and Technology* 59(11): 1810-1818.

Luukkonen, Terttu, Tijssen, Robert J.W., Persson, Olle and Sivertsen, Gunnar (1993): The measurement of intenational scientific collaboration. *Scientometrics* 28(1): 15-36.

Morillo, Fernanda, Bordons, María and Gómez, Isabel (2003): Interdisciplinarity in science: A tentative typology of disciplines and research areas. *Journal of the American Society for Information Science and Technology* 54(13): 1237-1249.

Moya-Anegón, Félix de, Vargas-Quesada, Benjamín, Chinchilla-Rodríguez, Zaida, Corera-Álvarez, Munoz-Fernández and Herrero-Solana, Victor (2007): Visualizing the Marrow of Science. *Journal of the American Society for Information Science and Technology* 58(14): 2167-2179.

Small, Henry and Garfield, Eugene (1985): The geography of science: disciplinary and national mappings. *Journal of Information Science* 11: 147-159.

Snow, Charles P. (1959): The two cultures and the scientific revolution. Rede Lecture. New York: Cambridge Univ. Press.

Van Leuwen, Thed and Tijssen, Robert (2000): Interdisciplinary dynamics of modern science: analysis of cross-disciplinary citation flows. Research Evaluation 9(3): 183-187.