A Bibliometric Test of the Hierarchy of the Sciences: Preliminary Results

Daniele Fanelli[*] and Wolfgang Glänzel[**]

[*] *dfanelli@staffmail.ed.ac.uk*
ISSTI-The University of Edinburgh, Old Surgeons' Hall, Edinburgh, EH1 1LZ, UK

[**] *Wolfgang.Glanzel@econ.kuleuven.be*
Centre for R&D Monitoring (ECOOM) and Dept. MSI, KU Leuven, Leuven, Belgium
Dept. Science Policy & Scientometrics, LHAS, Budapest, Hungary

Introduction

The existence of a hierarchy of the sciences and the possibility to measure the hardness of disciplines are matters of research and debate (e.g. Fanelli, 2010; Nicolaisen & Frandsen, 2012). Intuitively, a field's accuracy, precision and level of scholarly consensus should decline in proportion to the complexity of subject matter—e.g. when moving form physical to social phenomena. However, the many studies that tried to test this idea yielded contradictory results (e.g. Cole, 1983; Simonton, 2006). Most of these studies however, are limited by small size, unrepresentative sampling and by ignoring confounding factors.

To help solve this controversy, we intend to measure several parameters that previous studies suggested would reflect a study's hardness, in a large random sample of papers. In this poster we report preliminary results of this project, obtained on a smaller sample of papers, measuring the following parameters:

Length of title: harder disciplines should aim to convey specific findings, in the most economic way possible. Therefore, titles in harder disciplines should have more substantive words, especially when correcting for the length of the article itself. Measures: total number of words in the title, divided by number of pages (see below).

Length of abstract: based on the same logic as above, we hypothesised that the length of abstracts might also correlate with hardness. Measure: total number of words in the abstract.

Length of article: in softer disciplines, where the consensus is hypothesised to be lower, papers need to provide a full background to the study reported, and need to interpret and discuss the results at greater length. Therefore, the length of articles should inversely correlate with hardness. Measure: total number of pages.

Number of references: for the same reasons as above, the number of references cited should increase in "softer" studies. Measure: total number of references cited in the article

Citations to books: as explained above, "softer" sciences are hypothesised to deal with greater complexity and lower consensus, and to refer more often to older literature. Books and book chapters, therefore, should be cited more often than periodicals, and other forms of scientific communication (Glänzel & Schoepflin, 1995). Books were identified reliably by searching each title and author in Google-Books.

Diversity of cited sources: the higher focus and consensus of "harder" disciplines is hypothesised to lead to a concentration of the literature in fewer outlets, manifested in a reduced diversity of journals cited. The greater citation of books amongst softer disciplines can be considered a consequence of the opposite tendency (see above). Measures: Shannon, Simpson and Gini diversity indices.

Age distribution of references: as de Solla Price (1970) showed, a key aspect of "harder" sciences may be the speed with which they "metabolize" new findings, leading to a negatively skewed distribution in the age of references. We verified whether fitting a Poisson distribution would be more powerful than Price's index.

Oldest reference cited: this parameter complements the measure above, to encompass the range as well as the shape of the distribution. Measures: minimum year in references list. Since books are cited in recent editions, we also recorded the minimum year yielded by searches in Google-Books.

Direction of references: disciplines studying more fundamental problems should have little need to base their research from theories and findings outside their domain, and in particular from "softer" domains dealing with systems of higher levels of complexity. To classify the cited references, an algorithm matched the cited source to abbreviations listed in various literature databases, the classification of which gave us one or more possible disciplines, from which the general domain could be reliably identified. Measures: number of citations to journals outside the domain, and proportion of these directed to lower domains (e.g. from biological to physical sciences).

Frequency of citations: the higher focus and "rapid metabolism" of harder disciplines should lead to higher citation frequencies. Measure: number of citations counted at time of sample collection.

Number of authors: the higher precision, consensus and focus of harder disciplines should increase the level of collaboration and division of labour. Measure: total number of authors.

Materials and Methods

Sample

We randomly sampled 100 papers from journals listed in Thompson-Reuter's Essential Science Indicators database, for each of the following disciplines (in order of hypothesised hardness): Mathematics, Space Science, Physics, Chemistry, Biology & Biochemistry, Plant and Animal Sciences, Environment/Ecology, Psychiatry/Psychology, Economics & Business, Social Sciences General. In addition, we searched journals from the Arts and Humanities citation database. The final sample consisted of 1,200 papers, and a total of 35,844 cited references.

Analysis

The ability of each parameter to predict the hypothesised rank of a paper's discipline or domain was tested with an ordinal regression. Factors were examined singly and all together, and alternatively including and excluding the two extremes (Mathematics and Arts and Humanities).

Results

The various analyses yield rather coherent results. Most parameters significantly predicted the putative "hardness" of a paper's discipline or domain, but the magnitude of effect sizes was small in many cases (see Table 1).

Table 1. Multiple ordinal regression, with domain rank as dependent variable. Predictors are listed by decreasing effect magnitude. [Data sourced from Thomson Reuters Web of Knowledge]

FACTOR	B	SE	Z-value
prop. refs. to books	-2.31	0.01	-342.08
Price index, on journals	1.39	0.01	122.44
prop. refs. to harder domain	-0.99	0.18	-5.39
Shannon diversity (sources)	-0.53	0.09	-6.05
length of title/n. of pages	0.27	0.10	2.74
n. of pages	-0.08	0.01	-7.90
n. citations	-0.01	0.00	-2.81
oldest year in refs.	0.00	0.00	4.17
length of abstract	0.00	0.00	3.85
n. refs outside domain	0.01	0.01	0.67
total n. of refs	0.02	0.00	4.81
n. of authors	0.03	0.01	2.71

Strongest predictors identified were: the proportion of books in references (Fig. 1A), Price's index measured on journal-type references (which turned out to have very similar effects to the measures of skewness we tested, with the advantage of being simpler to calculate and more robust), the proportion of references to harder domains (Fig. 1B), the diversity of sources (Shannon gave the clearest results), and the length of title corrected for article length.

Conclusions

These preliminary results support the existence of a Hierarchy of the Sciences and the possibility to estimate a field's hardness using bibliometric parameters. However, many hypothesised differences are very small, and with within-discipline variability might challenge conventional classifications.

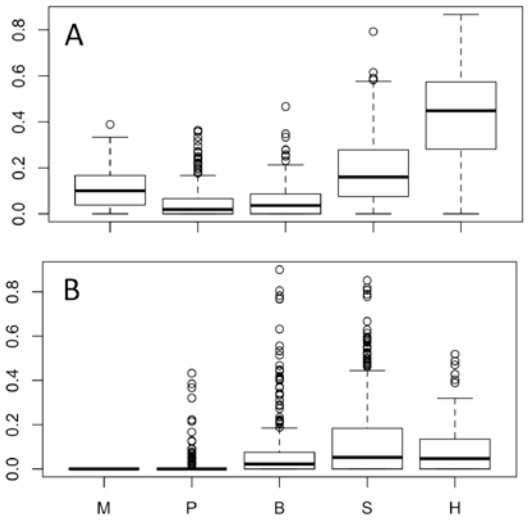

Figure 1. see text for explanations. Legend: (M mathematics, P physical sciences, B biological sc., S social sc., H humanities) [Data sourced from Thomson Reuters Web of Knowledge]

Acknowledgments

Bart Thijs gave helpful suggestions, Google-Books kindly increased its search limits to allow automatic searches. DF was funded by a Leverhulme Early-Career fellowship.

References

Cole, S. (1983). The Hierarchy of the Sciences? *American Journal of Sociology*, 89 (1), 111-139.

Fanelli, D. (2010). "Positive" Results Increase Down the Hierarchy of the Sciences. *Plos One*, 5 (3).

Glänzel, W. & Schoepflin, U. (1995). A Bibliometric Study on Ageing and Reception Processes of Scientific Literature. *Journal of Information Science*, 21 (1), 37-53.

Nicolaisen, J. & Frandsen, T.F. (2012). Consensus Formation in Science Modeled by Aggregated Bibliographic Coupling. *Journal of Informetrics*, 6 (2), 276-284.

Price, D.D. (1970). *Citation Measures of Hard Science, Soft Science, Technology, and Non-Science*. In C.E. Nelson, D.K. Pollak, (Eds), Communication among Scientists and Engineers, Heat, Lexington, Mass., 1-12.

Simonton, D.K. (2006). Scientific Status of Disciplines, Individuals, and Ideas: Empirical Analyses of the Potential Impact of Theory. *Rev. of General Psychology*, 10 (2), 98-112.