Report on the bibliometric indicators of Innogen (2002-2010)

October 2012

Ismael Rafols (*Ingenio*, Univ. Pol. València & SPRU, Univ. Sussex)
Rodrigo Costas (CWTS, University of Leiden)

Summary

The report explores the scientific impact and the interdisciplinary scope of the centre Innogen at the University of Edinburgh for the period 2002 to 2011. To do so, the report analyses publications by Innogen that are covered in the Web of Science (WoS). These are less than half of Innogen's publications as a result of the policy and humanities orientation of part of Innogen's research, areas which are not well covered in WoS.

The main finding is that Innogen research spans a wide diversity of disciplines and links scientific fields that are generally weakly connected, in particular various social sciences, health sciences and biomedicine. The wide diversity of disciplines is found at multiple levels: in terms of the knowledge base it draws on (as seen from references), the knowledge it creates (as suggested by the journals where it publishes) and the audience it has reached (as shown by articles citing Innogen's work). This finding is in alignment with Innogen's mission as interdisciplinary centre.

The second finding is that Innogen's scientific impact stands at the same level as the aggregated impact of the University of Edinburgh. We notice that simple citation counts tend to underestimate Innogen's contribution, since many of Innogen's publications are in subject areas with less propensity to cite and being cited.

Important notice: Given that Innogen is an interdisciplinary centre active in both academic and policy debates, a bibliometric characterisation is highly problematic and the insights of this study need to be taken only as suggestive and exploratory. This is because many of its publications are not conventional articles in journals indexed in the Thomson-Reuter's Web of Science (WoS). For example, a sizable part of Innogen's publications appear in biology journals classified as 'Editorial material' rather than scientific contributions. Since this bibliometric study is based in publications indexed in the WoS up to 2010 and particularly n document types "articles", "letters" and "reviews", it can only cover around between ~30% (for impact analysis) and ~50% (for interdisciplinarity analysis) of Innogen´s publications. This figure is consistent with the percentage of references in Innogen's WoS indexed papers that is contained in the WoS (38.4%).

Data and methods

Innogen management provided us with 420 publications records. We searched these records in Thomson-Reuter's Web of Science (WoS). Of the original list, 209 publications were matched in WoS (211 not found). For the analysis of interdisciplinarity, we could use 184 publications (all document types for 2002-2011), 2378 references contained by these, and 1130 citations they received. Of these, only 132 publications could be used for the analysis of performance (125 articles, 5 reviews and 2 letters, for 2002-2010), given further restrictions on period (up to 2010) and document type.[1]

The interdisciplinarity of Innogen was analysed following part of the methodology in Rafols et al. (2012). This methodology is based on the assignation of articles to WoS Categories according to the journal of the publication. The distribution of publications across of WoS Categories is then used to visualise the disciplinary spread of the organisation over the map of science and to compute interdisciplinarity measures. The assignation of articles to WoS is problematic and inaccurate, but has been shown to provide robust insights at the global science map level (this is accepting low resolution in terms of subdisciplines).

We have calculated bibliometric CWTS standard indicators following the new methodology and improvements of bibliometric indicators carried out at CWTS (see Waltman et al, 2011a, 2011b). The most important details regarding the main bibliometric indicators computed in this report can be found in Appendix I.

1. Measures and maps of interdisciplinarity

1.1. Disciplinary profile

One of Innogen's unique characteristics is its high degree of interdisciplinarity. This is shown by the spread of its own publications over diverse disciplines, and corroborated by the fact that the references in the publications and the citations received are also widely distributed across various disciplines.

This is shown in Table 1 and Figures 1, 2 and 3. We provide a comparison with the Imperial Business School (which includes one Health Management and one Innovation Management units –and is thus expected to have some interdisciplinary research) and with the more traditional London Business School. Innogen is active across disparate disciplinary areas, in

[1] Of the 209 WoS matched, 56 publications were published before 2002 or after 2010 and were not included in the analysis of performance. Publications after 2010 cannot be used for the analysis because they have no sufficient time to accrue citations when the analysis is carried out (August 2012). Other 21 publications could not be used because they were editorial materials (17) and book reviews (4).

particular over many social sciences areas plus the areas of health services and the basic biological sciences (which include some medicine and are thus called 'biomedical').

In comparison, the Business Schools are much more narrowly focused in a few social sciences (mainly business, management, economics and finance) and their activity in the biological area is very small. Innogen not only publishes and references diverse disciplines, but it also receives citations from diverse disciplines. This is important because it suggests that its papers not only draw on diverse knowledge, but also succeed on being of interest to diverse scientific audiences, both in the natural and social sciences.

Table 1. Disciplinary distribution of Innogen's publications, references and received citations.

	Innogen			**Imperial Business School**			**London Business School**		
Disciplinary Area	Pubs	Refs	Cits	Pubs	Refs	Cits	Pubs	Refs	Cits
Econ., Politics and Geography	28%	24%	20%	31%	29%	27%	37%	34%	36%
Biological Sciences	16%	19%	17%	1%	2%	2%	0%	1%	1%
Business and Management	22%	17%	17%	32%	36%	35%	43%	37%	38%
Health Services	19%	16%	20%	14%	7%	8%	0%	0%	1%
Clinical Medicine	2%	5%	5%	5%	5%	6%	0%	0%	0%
Psychology	2%	4%	4%	2%	2%	1%	7%	10%	5%
Sociol Studies	5%	4%	4%	1%	3%	1%	1%	2%	1%
Ecological Sciences	2%	3%	2%	0%	0%	0%	0%	0%	0%
Computer Science	1%	1%	2%	7%	4%	10%	8%	6%	12%
Agriculture	3%	1%	3%	0%	0%	0%	0%	0%	0%
Environmental S&T	1%	1%	2%	0%	0%	2%	2%	1%	1%
Cognitive Sciences	0%	1%	1%	0%	1%	1%	0%	2%	1%
Infectious Diseases	0%	1%	1%	1%	3%	3%	0%	0%	0%
Chemistry	0%	0%	1%	0%	0%	0%	0%	0%	0%
Engineering	0%	0%	0%	5%	6%	2%	2%	6%	4%
Geoscience	0%	0%	1%	0%	0%	0%	0%	0%	0%
Materials Science	0%	0%	1%	0%	0%	0%	0%	0%	0%
Physics	0%	0%	0%	0%	1%	1%	0%	0%	0%

1.2. Interdisciplinary citations

One research centre may have broad disciplinary base but not necessarily make connections between these disciplines. In order to investigate the extent of integration of diverse discipline, we compare the citation patterns that would be expected given Innogen's publication areas and the conventional citation patterns in the Web of Science. Figure 4 shows that, whereas one would expect citations only within disciplinary areas (blue lines in Figure 5a), Innogen citations cross the map of science bridging disciplines.

Figure 5 shows the Observed over Expected ratio of citations –which illustrate which of Innogen's citation are unexpected, or, in other words, where are Innogen's cross-citations 'unique'. The map shows that the special contribution of Innogen's citation is precisely to bridge disciplines between a triangle formed by social sciences, health services research and basic biological areas. Within Innogen's production, one can observe a difference in the extent of cross-citation between the 'softer' social sciences and economics. In the case of the former, they cross-cite over large cognitive distances, towards health and biomedicine, crosses over the 'empty' core of the map of science which reflects C.P. Snow's 'two cultures' of science. However, the economics side of Innogen only cites above expectation within the social sciences –hence it is an economics more engaged with other social sciences, but apparently not with the natural sciences.

The insights provided by the maps regarding the remarkable breadth of Innogen, and its exceptional degree of cross-citation can be further substantiated using indicators of interdisciplinarity. This is shown in Table 2. Several measures are used in order to convey different aspects of diversity, namely, the number of categories covered (variety), the balance between these categories (balance) and their relative cognitive distance (disparity) (Stirling, 2007). The Rao-Stirling diversity offers a comprehensive composite indicator that integrates the three dimensions. Shannon entropy is included for comparison as a conventional (though less accurate) traditional diversity indicator. The methods are described in detail in Rafols et al. (2012). The measures confirm that the disciplinary breadth of Innogen is larger from all perspectives –hence providing robust evidence.

As a measure of interdisciplinary citation, the mean distance between citing WoS category and cited WoS category is also provided. Again, Innogen's citations span larger distances than those of the comparators. Finally, a measure of Coherence is computed to gauge the degree of field cross-citation discounting for the disciplinary diversity. Even in this case, Innogen shows a higher value: this means that not only it covers a wider disciplinary space, it cross-cites more across its own disciplines than organisations covering a smaller knowledge territory.

Table 2. Indicators of disciplinary diversity and interdisciplinary citations.

	Innogen	Imperial Business	LBS
Disciplinary diversity			
Publications			
Rao-Stirling Diversity	***0.78***	***0.72***	***0.60***
Number of WoS Categories	26	15	9
Balance	0.85	0.74	0.67
Disparity	0.81	0.72	0.77
Shannon Entropy	3.46	2.97	2.34
References			
Rao-Stirling Diversity	***0.81***	***0.73***	***0.68***
Number WoS Categories	26	17	15
Balance	0.79	0.65	0.57
Disparity	0.83	0.83	0.82
Shannon Entropy	3.92	3.25	2.80
Citations			
Rao-Stirling Diversity	***0.83***	***0.75***	***0.68***
Number WoS Categories	30	20	15
Balance	0.83	0.73	0.65
Disparity	0.83	0.82	0.77
Shannon Entropy	4.13	3.48	2.98
Interdisciplinary citations			
Cognitive distance (mean)	0.56	0.45	0.32
Coherence (Cognitive Distance/RS Diversity)	0.72	0.60	0.54

2. Indicators of scientific impact

Citation counts have been adopted in the last decades as indicators of scientific impact, in spite of well known shortcoming (Martin and Irvine, 1983). Given the disciplinary breadth of Innogen, it is very important to take into account disciplinary differences in citation behaviour across fields when carrying out its scientific impact assessment. This is because the opportunity to receive citations varies greatly among fields due to different community size, as well as different publication and citation practices. This renders the assessment of interdisciplinary units unavoidably very problematic (see discussion in Rafols et al., 2012, pp. 1272-1275).

The conventional method to measure citations is to compare the citations of articles that are published in the same field or journal (Waltman et al, 2011a, 2011b). This is the main form of normalisation we will use –while acknowledging that it is not without limitations. For example, a review published in *Trends in biotechnology* by Innogen researchers is compared to the citation of other articles in the field of *Biotechnology & Applied Microbiology*, which are mainly biology based articles rather than equivalent policy-oriented publication. As a result, there is the possibility that Innogen's citation in some fields is underestimated.

Here we used three of two of the field normalised indicators, and one journal normalisation, which we compare with the absolute number of citations per paper (a much mis-used indicator):

- MNCS: field-normalised citations per paper. This is the mean of the ratio of observed vs. expected number of citations in a WoS category.
- PP (top10%): percentage of citations among the top 10% most cited in the field.

Fore comparison, we have used data for three universities from the Leiden Ranking of universities for 2011-12 (http://www.leidenranking.com/ranking.aspx).[2]

Table 3. Scientific impact indicators

	Innogen	Univ. Edinburgh	Univ. Cambrige	Univ. Sussex
MNCS	1.21	1.28	1.53	1.17
PP (top10%)	15.7%	14.4%	16.7%	12.4%

The results suggest that Innogen's papers are accruing a number of citations similar to the norm in the University of Edinburgh, this is more than 20% above the expected mean, and with about 15% of its papers among those 10% most cited. A more careful analysis shows that Innogen is receiving less citation per paper than the University of Edinburgh in terms of the mean but it has a higher percentage of publications among the top 10% most cited. This difference means that Innogen has not had star publications with an extraordinary number of citations (which would have lead the mean to be higher), but that it has sustained a good proportion of high-impact papers.

Let us emphasize the indicators used in this analysis are professional bibliometrics citation measures, with adequate field-normalisation. If one carried out quick-and-dirty desktop bibliometrics (as some managers are sometimes tempted to do) without considering differences in fields, one would find that Innogen's publication have a lower absolute number of citations per paper (5.94) than the average of the Universities of Edinburgh (9.01), Cambridge (10.91) or Sussex (7.29). However such differences are attributable to the fact that most of Innogen's publications lie in the social sciences and humanities, i.e. in fields

[2] Here we have to take into account the difference in time periods included in this study and in the Leiden Ranking – e.g. the Leiden Ranking focuses on publications during the period 2005-2009 and excludes the Arts & Humanities papers.

which in average have less citations per paper. The appropriate measure of impact is only found taking into account field differences in citation behaviour. However, it is possible, even in this case, that the impact interdisciplinary research is underestimated given the fact that in interdisciplinary articles may not be in agreement with the main discipline of the journals in which they are published (see discussion in Rafols et al, 2012, pp. 1276-1277).

3. Conclusions

The analysis of Innogen's publications suggests that Innogen is a highly interdisciplinary centre, linking various social science with studies on publich health and biological sciences. Such finding appears to be consistent with Innogen's mission. Within the social sciences, more interaction with the natural sciences was observed from the "softer" social sciences than from the economics.

The analysis of citations has revealed Innogen's publications to have a similar scientific impact to that of the average of the University of Edinburgh. This is below the performance of top UK universities such as Cambridge, but above other research-focused universities such as Sussex.

A strong caveat applies to this conclusion: all this analysis has been carried out with less than 50% of Innogen's publication due to lack of broader coverage in the Web of Science.

Figure 1a. Publications of Innogen (2002-2010) overlaid on the global map of science.

The grey lines of background represent the landscape of the global map science (created with all Web of Science data for 2009). This map provides a relative position of subject areas according to the similarity of their citation patterns. The number of publications of Innogen in each area is shown by the size of the WoS category node. Publication in distant areas in the map reflects publication activity is cognitively disparate disciplines. Innogen is particularly active in various social science areas, from more social studies (yellow), to business (pink) and economics (light green), as well as in health policy and services (dark pink) and biological sciences (green) such as genetics and cell biology.

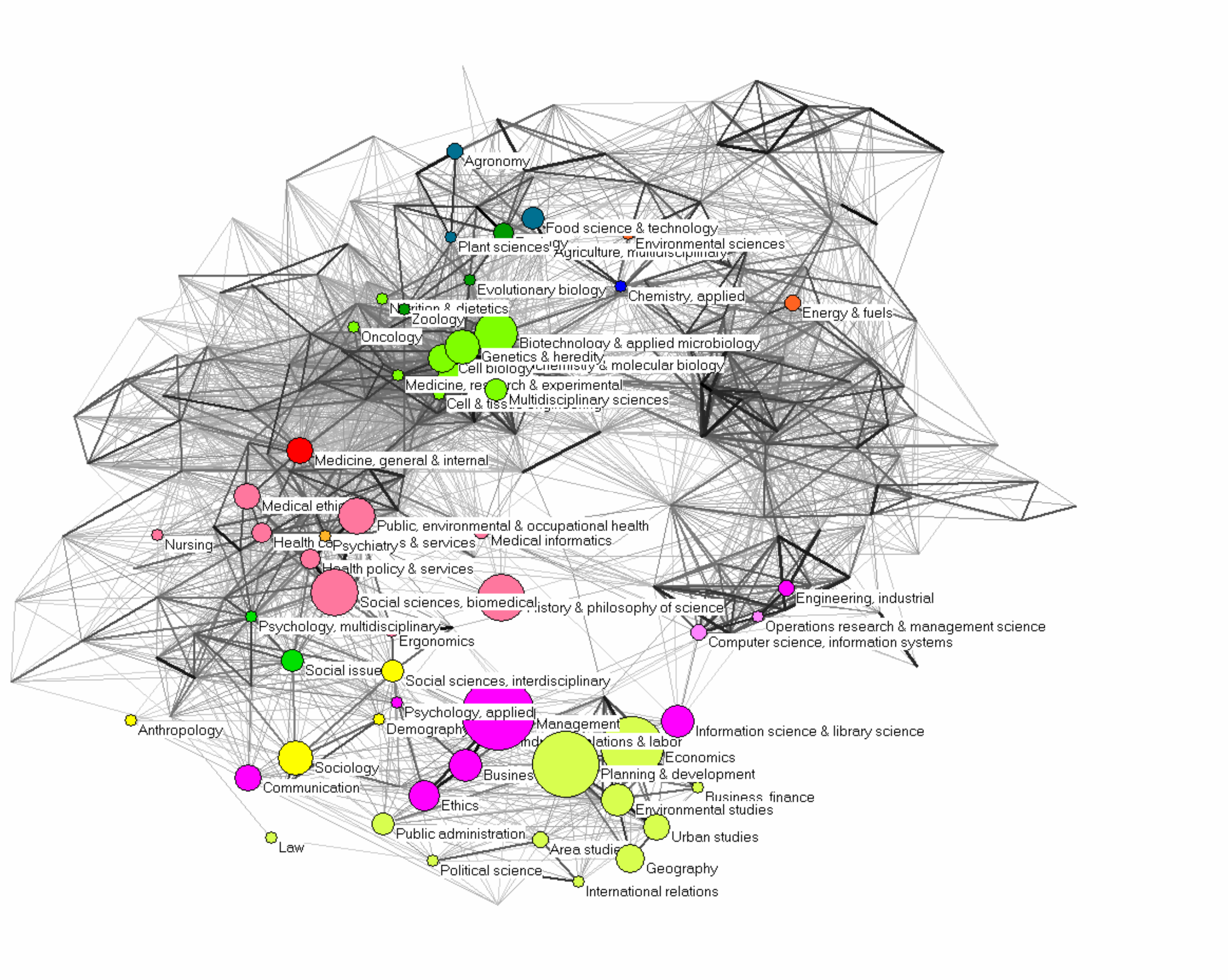


Figure 1b. Comparison: Publications of Imperial Business School (2006-2009) overlaid on the global map of science. The grey lines in the background show the global map of science, described in Fig. 1a. However, now the size of the nodes reflects the number of publications by Imperial Business School in a field. The fact that publications are now located in fewer areas shows that Imperial Business School has much less disciplinary spread than Innogen. Its main focus is in management (light pink), business and economics (light green), although, strangely for a business school, imperial has some activity in health services (dark pink)

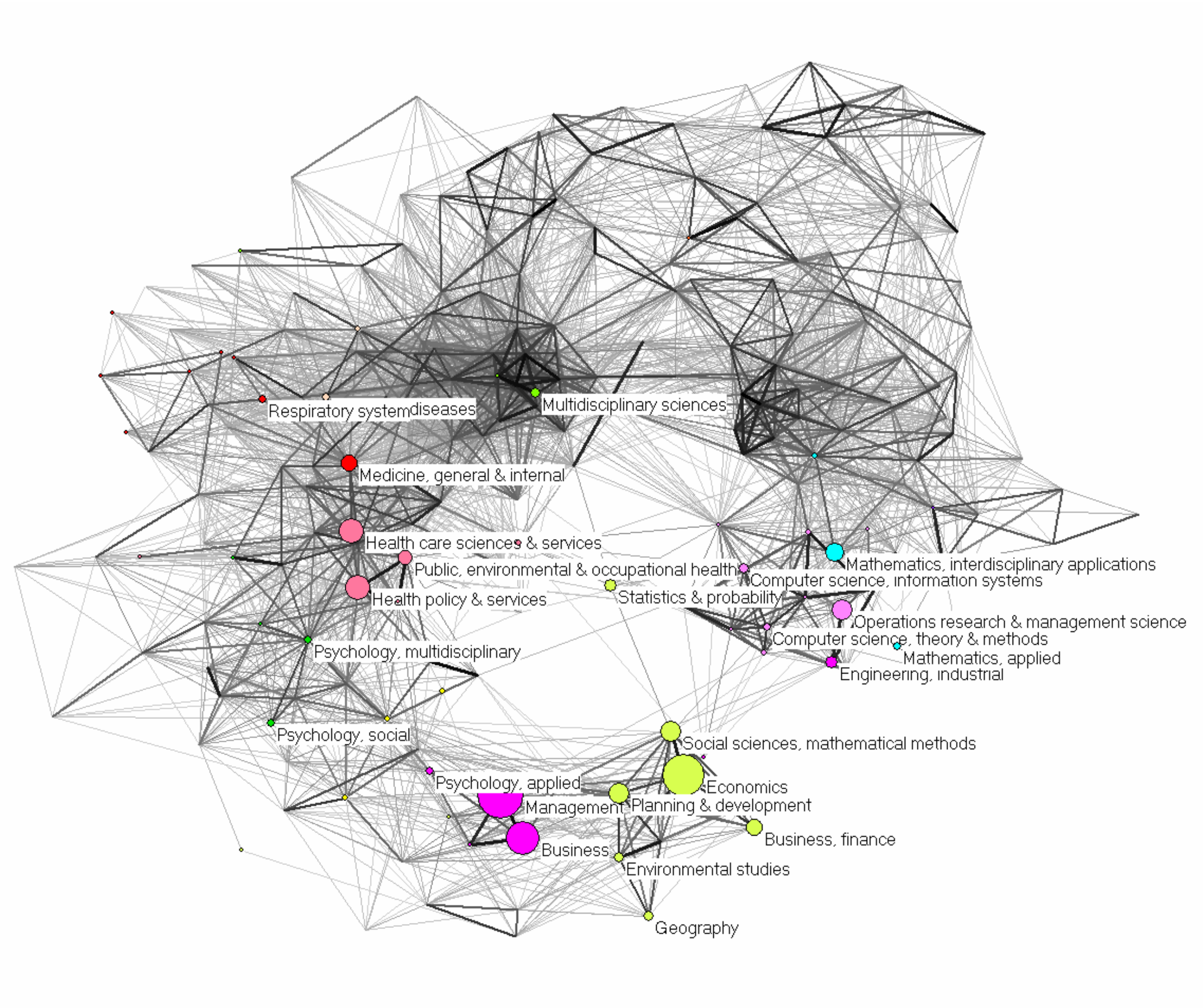


Figure 2a. References in Innogen publications overlaid on the global map of science. The grey lines in the background show the global map of science, described in Fig. 1a. The size of the nodes reflects the aggregate number of references to a given field from all Innogen's publications.

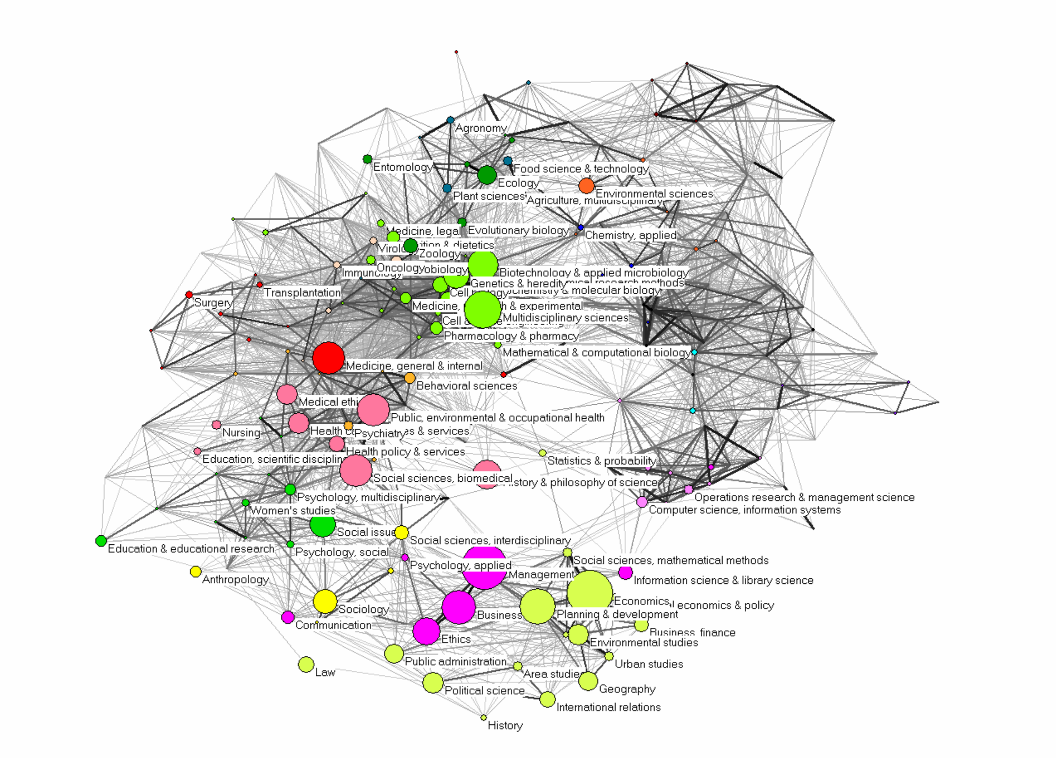


Figure 2b. References to publications of Imperial Business School (2006-2009) overlaid on the global map of science. The grey lines in the background show the global map of science, described in Fig. 1a. The size of the nodes reflects the aggregate number of references to a given field from all Imperial Business School's publications. Again, one observes much less disciplinary diversity.

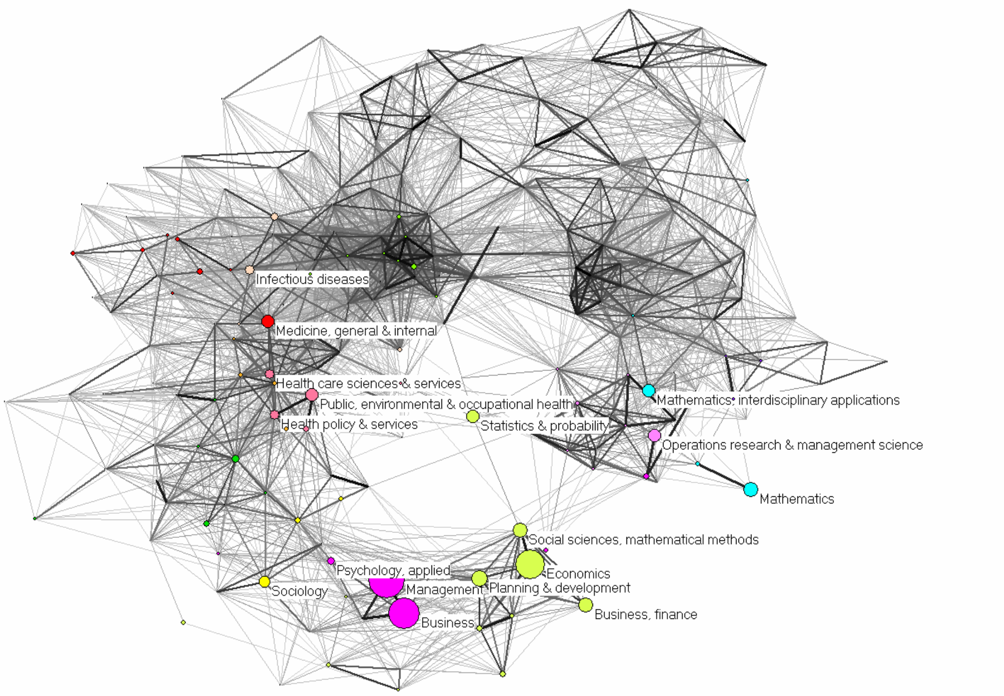


Figure 3a. Citations to Innogen publications over the global map of science. The grey lines in the background show the global map of science, described in Fig. 1a. The size of the nodes reflects the aggregate number of citations from a given field to all Innogen's publications.

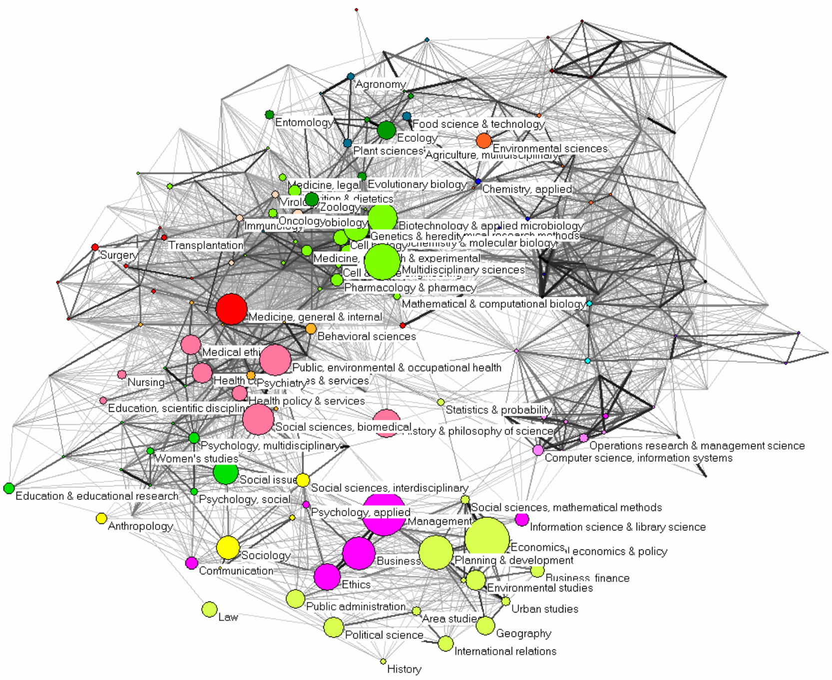


Figure 3b. Citations to publications of Imperial Business School overlaid on the global map of science. The grey lines in the background show the global map of science, described in Fig. 1a. The size of the nodes reflects the aggregate number of citations from a given field to all Imperial Business School's publications. Again the citations received by Imperial Business School are much less received than Innogen's.

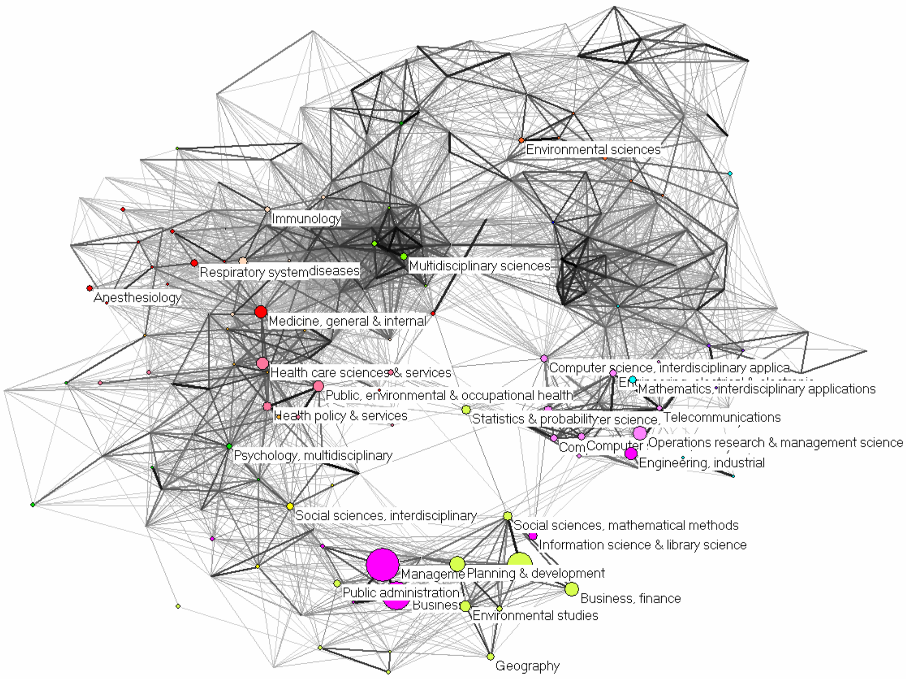


Figure 4a. Expected citations of Innogen across different Web of Science Categories.

The grey lines in the background show the global map of science, described in Fig. 1a. The size of the nodes reflects the aggregate number of citations given to a field from all Innogen's publications. Blue lines show the expected citations between fields, given where Innogen is publishing. These expected citation are within disciplines: within biological sciences, within health services, and within social sciences. (Only citations larger than 0.2% are shown).

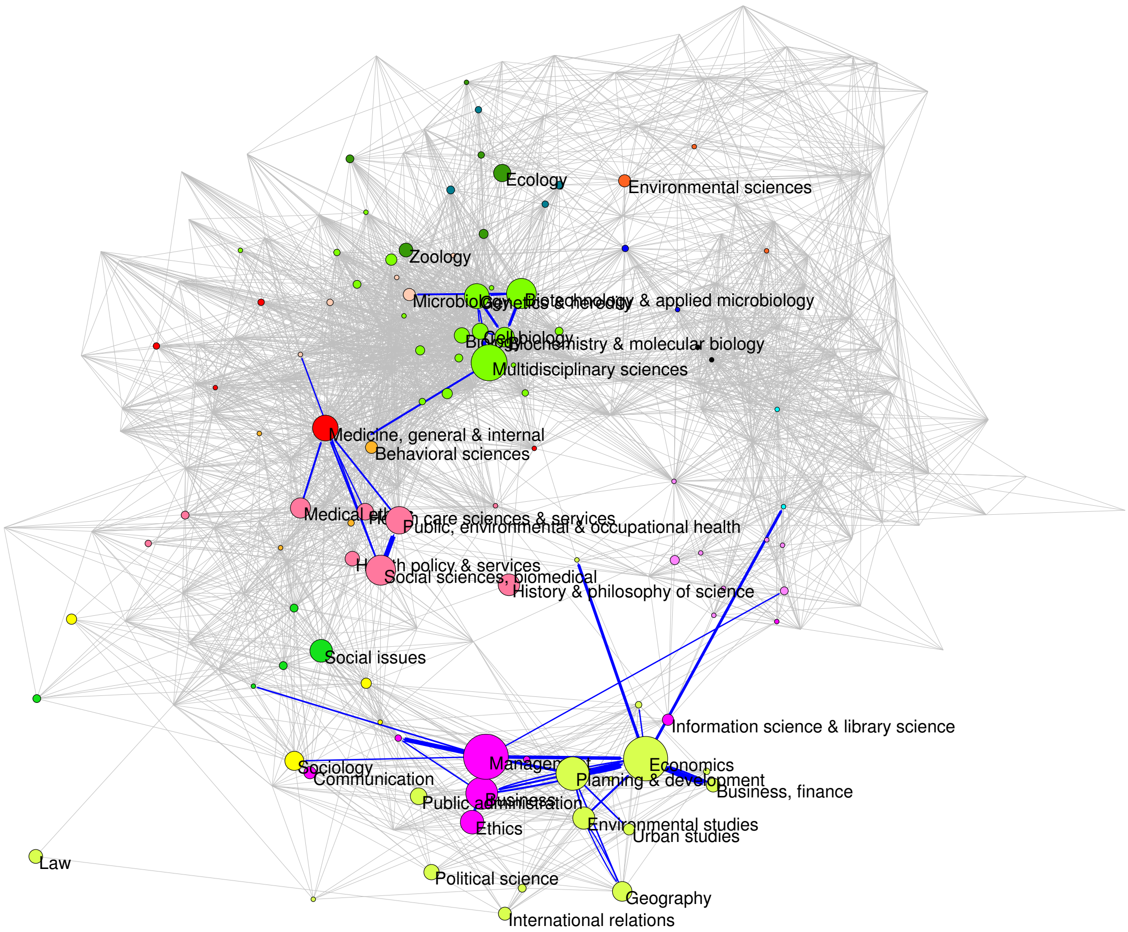


Figure 4b. Observed citations of Innogen across different Web of Science Categories.

The grey lines in the background show the global map of science, described in Fig. 1a. The size of the nodes reflects the aggregate number of citations given to a field from all Innogen's publications. Orange lines show the citations between fields observed in Innogen's publications. The citations between fields criss-cross the map of science both within disciplines and across disciplines. (Only citations larger than 0.2% are shown).

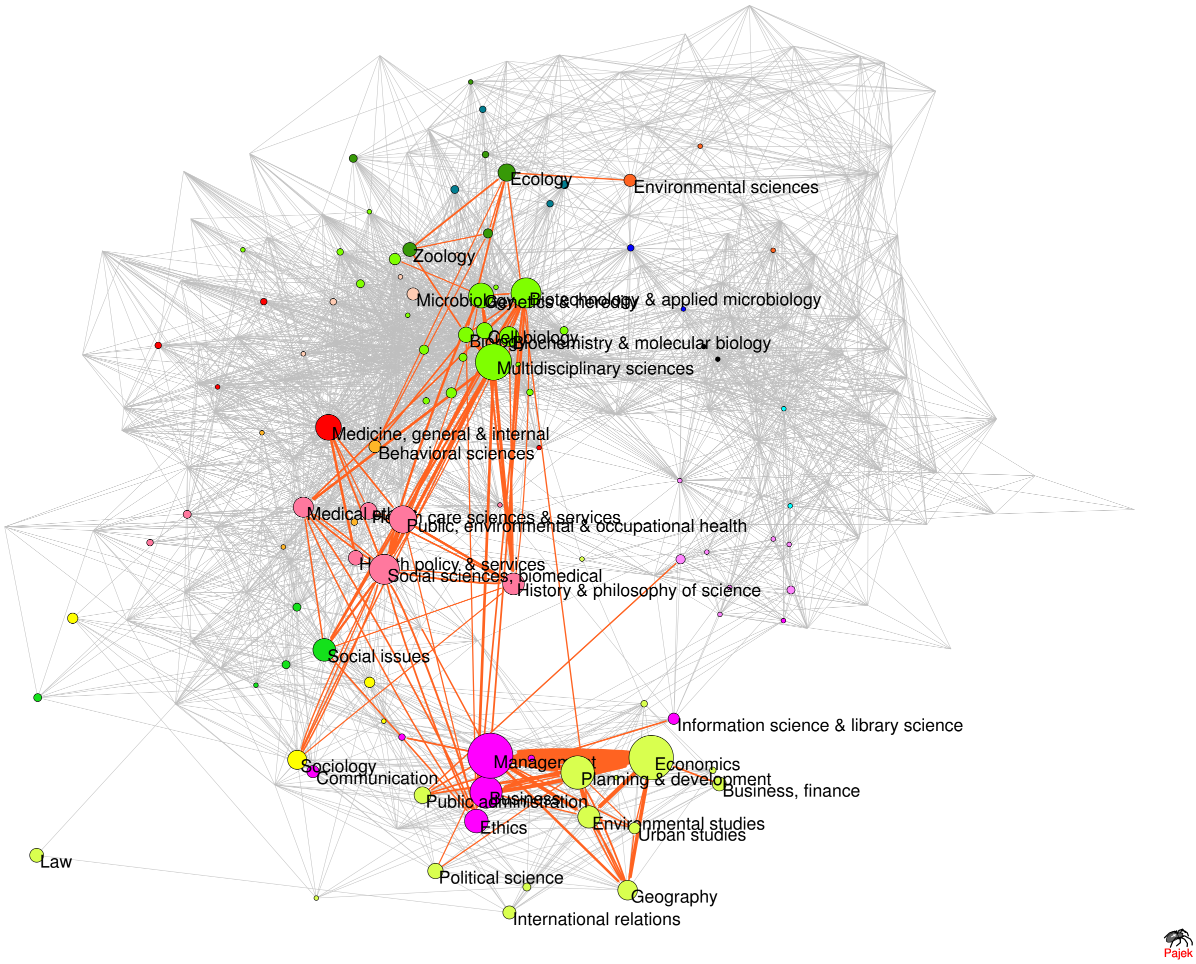
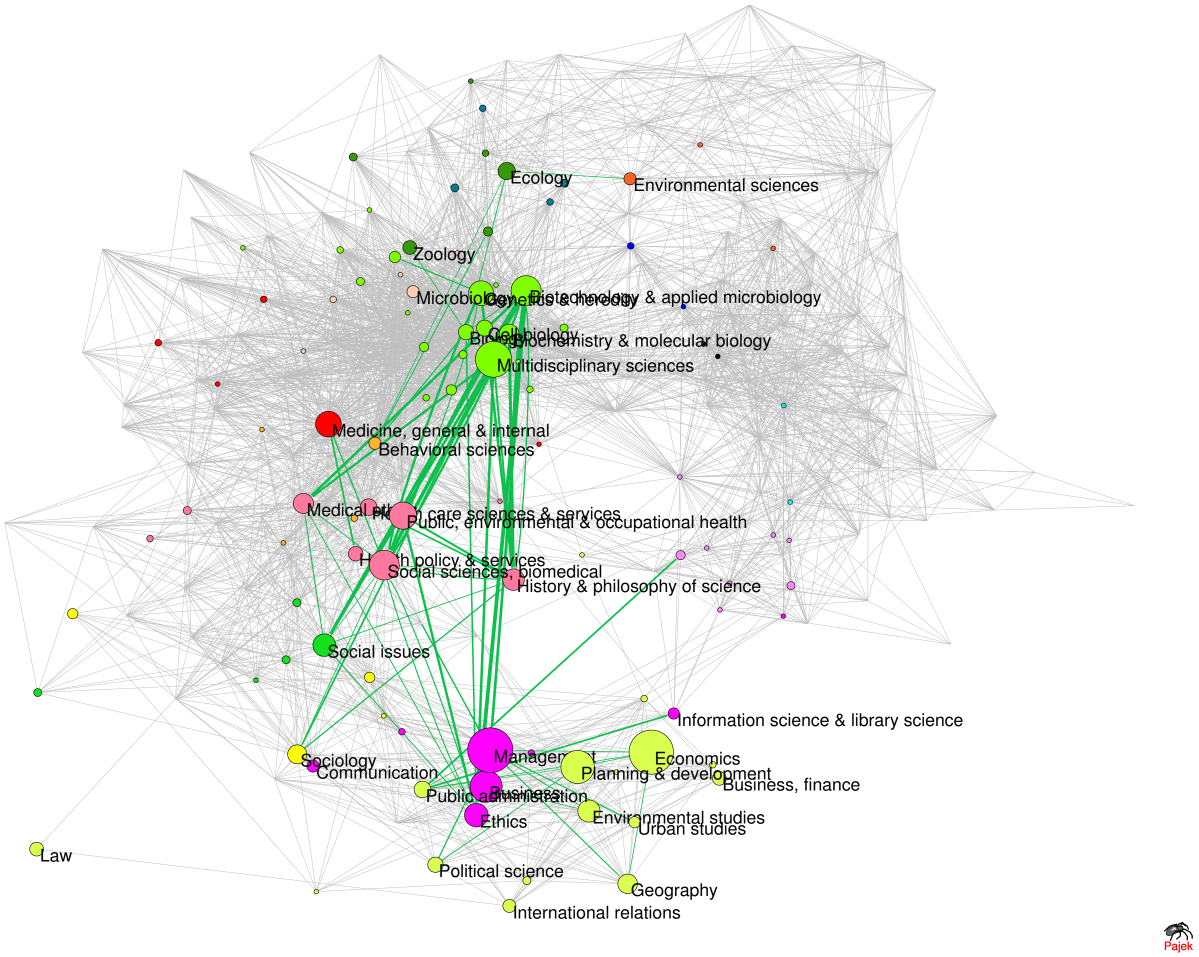


Figure 5. Ratio of Observed/Expected citations of Innogen across different Web of Science Categories. The grey lines in the background show the global map of science, described in Fig. 1a. The size of the nodes reflects the aggregate number of citations given to a field from all Innogen's publications. The green lines representing the ration of Observed/Expected citations illustrate the unexpected degree of cross-citation carried out by Innogen publications. Such unexpected cross-citation is a trace of interdisciplinary research. (Only ratios larger than 5, and for observed citations larger than 0.2% are shown).



References

Martin, B.R., Irvine, J., 1983. Assessing basic research: Some partial indicators of scientific progress in radio astronomy. Research Policy 12, 61–90.

Rafols, I., Leydesdorff, L. O'Hare, A., Nightingale, P. and Stirling, A. (2012) How journal rankings can suppress interdisciplinarity. A comparison of innovation studies and business & management. *Research Policy,* 41(7), 1262–1282.

Rafols, I., Porter, A. L. and Leydesdorff, L. (2010) Overlay science maps: a new tool for research policy and library management. *Journal of the American Society for Information Science and Technology* 61(9), 871–1887.

Stirling, A., 2007. A general framework for analysing diversity in science, technology and society. Journal of The Royal Society Interface 4, 707–719.

Waltman, L.; van Eck, N.J., van Leeuwen, T.N, Visser, M.S. and van Raan, A.F.J. (2011a). Towards a new crown indicator: some theoretical considerations. Journal of Informetrics, 5(1), 37-47.Waltman, L.; van Eck, N.J., van Leeuwen, T.N, Visser, M.S. and van Raan, A.F.J. (2011a). Towards a new crown indicator: an empirical analysis. Scientometrics, 87(3), 467-481.

Appendix I. Methodological aspects regarding the calculation of CWTS standard bibliometric indicators

Indicators of Output

To measure the total publication output of a unit, we use a very simple indicator. This is the number of publications indicator, denoted by ***P***. This indicator is calculated by counting the total number of publications of a research unit.

Indicators of Impact

A number of indicators are available for measuring the average scientific impact of the publications of a unit. These indicators are all based on the idea of counting the number of times the publications of a unit have been cited. Citations can be counted using either a fixed-length citation window or a variable-length citation window. In the case of a fixed-length citation window, only citations received within a fixed time period (e.g., three years) after the appearance of a publication are counted. In the case of a variable-length citation window, all citations received by a publication up to a fixed point in time are counted, which means that older publications have a longer citation window than more recent publications. An advantage of a variable-length window over a fixed-length window is that a variable-length window usually yields higher citation counts, which may be expected to lead to more reliable impact measurements. A disadvantage of a variable-length window is that citation counts of older and more recent publications cannot be directly compared with each other. Using a variable-length window, older publications on average have higher citation counts than more recent publications, making direct comparisons impossible. This difficulty does not occur with a fixed-length window. At CWTS, we mostly work with a variable-length window, where citations are counted up to and including the most recent year fully covered by our database. Furthermore, in the calculation of our impact indicators, we only take into account publications with a citation window of at least one full year. For instance, if our database covers publications until the end of 2011, this means that publications from 2011 are not taken into account, while publications from 2010 are, and citations up to 2011 will be counted for these 2010 publications.

In the calculation of our impact indicators, we disregard author self citations. We classify a citation as an author self citation if the citing publication and the cited publication have at least one author name (i.e., last name and initials) in common. We disregard self citations because they have a somewhat different nature than ordinary citations. Many self citations are given for good reasons, in particular to indicate how different publications of a researcher build on each other. However, sometimes self citations serve as a mechanism for self promotion rather than as a mechanism for indicating relevant related work. This is why we consider it preferable to exclude self citations from the calculation of our impact indicators. By disregarding self citations, the sensitivity of our impact indicators to manipulation is reduced. Disregarding self citations means that our impact indicators focus on measuring the impact of the work of a researcher on other members of the scientific community. The impact of the work of a researcher on his own work is ignored.
Our most straightforward impact indicator is the mean citation score indicator, denoted by ***MCS***. This indicator simply equals the average number of citations of the publications of a

unit. Only citations within the relevant citation window are counted, and author self citations are excluded. Also, only citations to publications of the document types: article, letter, and review are taken into account. In the calculation of the average number of citations per publication, articles and reviews have a weight of one while letters have a weight of 0.25.

A major shortcoming of the ***MCS*** indicator is that it cannot be used to make comparisons between scientific fields. This is because different fields have very different citation characteristics. For instance, using a three-year fixed-length citation window, the average number of citations of a publication of the document type article equals 2.0 in mathematics and 19.6 in cell biology. So it clearly makes no sense to make comparisons between these two fields using the ***MCS*** indicator. Furthermore, when a variable-length citation window is used, the ***MCS*** indicator also cannot be used to make comparisons between publications of different ages. In the case of a variable-length citation window, the ***MCS*** indicator favors older publications over more recent ones because older publications tend to have higher citation counts.

Our mean normalized citation score indicator, denoted by ***MNCS***, provides a more sophisticated alternative to the ***MCS*** indicator. The ***MNCS*** indicator is similar to the ***MCS*** indicator except that it performs a normalization that aims to correct for differences in citation characteristics between publications from different scientific fields, between publications of different ages (in the case of a variable-length citation window), and between publications of different document types (i.e., article, letter, and review). To calculate the ***MNCS*** indicator for a unit, we first calculate the normalized citation score of each publication of the unit. The normalized citation score of a publication equals the ratio of the actual and the expected number of citations of the publication, where the expected number of citations is defined as the average number of citations of all publications in WoS that belong to the same field and that have the same publication year and the same document type. The field (or the fields) to which a publication belongs is determined by the WoS subject categories of the journal in which the publication has appeared. The ***MNCS*** indicator is obtained by averaging the normalized citation scores of all publications of a unit. Like in the case of the ***MCS*** indicator, letters have a weight of 0.25 in the calculation of the average while articles and reviews have a weight of one. If a unit has an ***MNCS*** indicator of one, this means that on average the actual number of citations of the publications of the unit equals the expected number of citations. In other words, on average the publications of the unit have been cited equally frequently as publications that are similar in terms of field, publication year, and document type. An ***MNCS*** indicator of, for instance, two means that on average the publications of a unit have been cited twice as frequently as would be expected based on their field, publication year, and document type. We refer to Waltman, et al (2011a, 2011b) for more details on the ***MNCS*** indicator.

In addition to the ***MNCS*** indicator, we have another important impact indicator. This is the proportion top 10% publications indicator, denoted by ***PPtop 10%***. For each publication of a research group, this indicator determines whether based on its number of citations the publication belongs to the top 10% of all WoS publications in the same field (i.e., the same WoS subject category) and the same publication year and of the same document type. The PPtop 10% indicator equals the proportion of the publications of a research group that belong to the top 10%. Analogous to the ***MCS*** and ***MNCS*** indicators, letters are given less weight than articles and reviews in the calculation of the ***PPtop 10%*** indicator. If a research group has a ***PPtop 10%*** indicator of 10%, this means that the actual number of top 10% publications of the group equals the expected number. A ***PPtop 10%*** indicator of, for instance, 20% means that a group has twice as many top 10% publications as expected.

To assess the impact of the publications of a unit, our general recommendation is to rely on a combination of the ***MNCS*** indicator and the ***PPtop 10%*** indicator. An important weakness of the ***MNCS*** indicator is its strong sensitivity to publications with a very large number of citations. If a unit has one very highly cited publication, this is usually sufficient for a high score on the ***MNCS*** indicator, even if the other publications of the group have received only a small number of citations. Because of this, the ***MNCS*** indicator may sometimes seem to significantly overestimate the actual scientific impact of the publications of a unit. The ***PPtop 10%*** indicator is much less sensitive to publications with a very large number of citations, and it therefore does not suffer from the same problem as the ***MNCS*** indicator. A disadvantage of the ***PPtop 10%*** indicator is the artificial dichotomy it creates between publications that belong to the top 10% and publications that do not belong to the top 10%. A publication whose number of citations is just below the top 10% threshold does not contribute to the ***PPtop 10%*** indicator, while a publication with one or two additional citations does contribute to the indicator. Because the ***MNCS*** indicator and the ***PPtop 10%*** indicator have more or less opposite strengths and weaknesses, the indicators are strongly complementary to each other. This is why we recommend taking into account both indicators when assessing the impact of a unit's publications.

It is important to emphasize that the correction for field differences that is performed by the ***MNCS*** and ***PPtop 10%*** indicators is only a partial correction. As already mentioned, the field definitions on which these indicators rely are based on the WoS subject categories. It is clear that, unlike these subject categories, fields in reality do not have well-defined boundaries. The boundaries of fields tend to be fuzzy, fields may be partly overlapping, and fields may consist of multiple subfields that each have their own characteristics. From the point of view of citation analysis, the most important shortcoming of the WoS subject categories seems to be their heterogeneity in terms of citation characteristics. Many subject categories consist of research areas that differ substantially in their density of citations. For instance, within a single subject category, the average number of citations per publication may be 50% larger in one research area than in another. The ***MNCS*** and ***PPtop 10%*** indicators do not correct for this within-subject-category heterogeneity. This can be a problem especially when using these indicators at lower levels of aggregation, for instance at the level of departments or individuals.

Indicators of journal impact

In addition to the average scientific impact of the publications of a unit, it may also be of interest to measure the average scientific impact of the journals in which the unit has published. In general, high-impact journals may be expected to have stricter quality criteria and a more rigorous peer review system than low-impact journals. Publishing a scientific work in a high-impact journal may therefore be seen as an indication of the quality of the work by itself.

We use the mean normalized journal score indicator, denoted by ***MNJS***, to measure the impact of the journals in which a unit has published. To calculate the ***MNJS*** indicator for a unit, we first calculate the normalized journal score of each publication of the group. The normalized journal score of a publication equals the ratio of on the one hand the average number of citations of all publications published in the same journal and on the other hand the average number of citations of all publications published in the same field (i.e., the same WoS subject category). Only publications in the same year and of the same document type are considered. The MNJS indicator is obtained by averaging the normalized journal scores of all publications of a unit. Analogous to the impact indicators, letters are given less weight than articles and reviews in the calculation of the average. The ***MNJS*** indicator is closely related to the ***MNCS*** indicator. The only difference is that instead of the actual number of citations of a publication the ***MNJS*** indicator uses the average number of citations of all publications published in a particular journal. The interpretation of the ***MNJS*** indicator is analogous to the interpretation of the ***MNCS*** indicator.