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Bibliometric analysis of HRB-supported publications 2000-12

Health Research Board

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1. Executive summary

This report was commissioned by the Health Research Board (HRB) which contracted Thomson Reuters (*Evidence*) to conduct a bibliometric analysis of HRB-supported publications between 2000 and 2012.

HRB-supported publications were matched to the Thomson Reuters *Web of Knowledge℠* and supplemented with data from the funding acknowledgement text, and then linked with HRB funding schemes and grant types.

This report analyses trends in research output and citation impact (Section 4) using HRB-supported journal papers. These are articles, reviews and some peer-reviewed proceedings papers used in citation analyses. It analyses the performance of HRB-supported papers by HRB strategic pillar areas and funding schemes (Section 5) and *Web of Science℠* journal categories (Section 6). It also analyses patterns of domestic and international co-authorship (Section 7) by volume and citation impact.

Key findings

- Some 3,382 HRB-supported publications in the 2000–12 period were matched to the *Web of Knowledge℠*; of these publications, 3,226 were papers used in citation analyses.
- HRB-supported papers have grown rapidly in volume terms, subject to important caveats set out in Section 3.2.1 in terms of the composition of the HRB publications file. Notwithstanding these caveats, the HRB has undoubtedly made an increasing contribution to Irish clinical/health/pre-clinical and biological sciences research, as well as to the wider Irish research base.
- The majority of HRB-supported papers have been published in high-impact journals, and over half have been published in the world's top 10% of journals as measured by journal impact factor.
- There has been a high uptake and use of HRB-supported papers. Very few papers prior to 2010 are uncited. One-fifth (18.9%) of HRB-supported papers are in the world's top 10% as measured by citation impact.
- The citation impact of HRB-supported papers is very high (1.74, 2000–12) and increasing, approaching twice the world average (1.84, 2008–12). This outperforms benchmarks for similar Irish and UK research in clinical/health/pre-clinical and biological sciences research.
- The Impact Profile® of HRB-supported papers outperforms benchmarks for similar Irish clinical/health/pre-clinical and biological sciences research.
- In terms of HRB strategic pillar areas, more than two-thirds of HRB-supported papers were in the Biomedical category; around one-fifth were Clinical and more than one-tenth were focused on Population Health and Health Services. The latter two HRB strategic pillar areas have increased as a share of HRB-supported papers, reflecting HRB's strategy to move increasingly into patient-oriented healthcare research.
- HRB-supported Clinical papers are cited over twice the world average (2.20). HRB-supported Biomedical papers are very well cited (1.67). Citation impact in these fields is driven by internationally co-authored papers (Section 7.3). HRB-supported Population Health and Health Services papers are well cited (1.40) and citation impact is increasing.
- Citation impact is particularly high in certain HRB funding schemes, particularly for schemes under the broad headings of Infrastructure and Special Initiatives, but also for Cancer

Consortium-related papers (notably the ICORG Cancer Clinical Trials Network). Funding schemes related to career development (such as the Clinician Scientist Awards, fellowships and PhD training programmes) are also cited more than average.

- With the exception of two fields (Cell Biology and Endocrinology & Metabolism), HRB-supported papers by its top 20 *Web of Science*^{SM} journal categories by volume are very well cited relative to the world average and relative to benchmarks for similar Irish clinical/health/pre-clinical and biological sciences research. The citation impact of HRB-supported papers in Oncology, Immunology, Genetics & Heredity and Psychiatry is particularly high.
- Around two-fifths of HRB-supported papers have been internationally (40.8%) and domestically (40.0%) co-authored. This has risen from around one-third of HRB-supported papers (33.8% and 34.7%, respectively) to over two-fifths (43.8% and 42.1%). Internationally co-authored HRB-supported papers are cited over twice the world average (2.28) and citation impact is rising.
- The citation impact of internationally co-authored papers in the HRB Clinical strategic pillar area is over three times the world average (3.29) compared to all papers in this strategic pillar area (2.20). In the HRB Biomedical strategic pillar area, internationally co-authored papers have a citation impact over twice the world average (2.11) compared to all papers in this strategic pillar area (1.67). The citation impact gain of internationally co-authored papers compared to all papers in the HRB Population Health and Health Services research strategic pillar area is more negligible (1.51 compared to 1.40, respectively). There is little difference in citation impact between the three HRB strategic pillar areas that were authored purely at the national level.
- Researchers from the USA and the UK have been the most frequent international co-authors of HRB-supported papers (43.6% and 43.1% of internationally co-authored papers, respectively) which suggests a strong Anglophone dimension to international co-authorship along with partners from countries such as Australia and Canada (10.3% and 8.1%, respectively). European partners also feature, particularly countries such as Germany (12.6%), Italy (8.7%) and France (8.7%). These partner countries are mapped in Section 7.5.
- The Irish academic sector has produced around 90% of HRB-supported papers and the Irish health sector has produced around one-third. These proportions have been more or less constant over time, although there are suggestions that the Irish health sector is producing a greater proportion of HRB-supported papers (Section 7.4).

2. Background

The Health Research Board (HRB) commissioned Thomson Reuters (*Evidence*) to conduct an analysis of the bibliometric impact of peer-reviewed publications associated with its research funding in Ireland. The dataset for these analyses was compiled from an internal HRB publications file which was matched to, and supplemented with, data from the Thomson Reuters *Web of Knowledge℠*.

The HRB wished to assess the scientific impact of the research it has funded since 2000 and to gain strategic insights in terms of trends in output and impact, and areas of strength and weakness. The HRB also wished to examine the extent of internationally and domestically co-authored research linked to HRB-supported papers.

2.1 Health Research Board

The HRB has a statutory responsibility to support, promote and commission health research and to manage health information systems in the areas of alcohol and drug use, disability and mental health. The HRB also has a core role in generating and synthesising high-quality research evidence for the Department of Health, in order to facilitate evidence-based policy-making.[1]

The HRB Strategic Business Plan 2010–14 marked a shift in strategic emphasis away from basic biomedical research, in order to increase capacity in Ireland for high-quality patient-oriented research, population health sciences, and health services research. The strategy recognises the importance of establishing a coordinated approach, so as to achieve the highest quality health research, and of developing the right skills, conditions and capacity in the Irish health system, in order to accelerate the translation of research discoveries into real benefits for people.

The publications analysed here relate principally to research funded by the HRB from 2000 to 2009 (although output from more recent grants is also captured). In that period, the HRB funded research across the entire spectrum of health research, including basic biomedical research, translational research, clinical research, health services research and population health sciences.

2.2 Thomson Reuters

Thomson Reuters is the world's leading source of intelligent information for business and professionals. It combines industry expertise with innovative technology to deliver critical information to leading decision- makers in the financial, legal, tax and accounting, healthcare, science and media markets, powered by the world's most trusted news organisation. Visit www.thomsonreuters.com for more information.

Thomson Reuters Research Analytics is a suite of products, services and tools that provide comprehensive research analysis, evaluation and management. For over half a century Thomson Reuters has pioneered the world of citation indexing and analysis, helping to connect scientific and scholarly thought around the world. Today, academic and research institutions, governments, not-for-profits, funding agencies, and all others with a stake in research need reliable, objective methods for managing and measuring performance. Thomson Reuters Custom Analytics & Engineered Solutions provides reporting and consultancy services within Research Analytics using customised analyses to bring together several indicators of research performance in such a way as to enable

[1] http://www.hrb.ie/about/corporate/

customers to rapidly make sense and interpret of a wide range of data points to facilitate research strategy decision-making.

Thomson Reuters (*Evidence*) has extensive experience with databases on research inputs, activity and outputs, and has developed innovative analytical approaches for benchmarking, interpreting and visualisation of international, national and institutional research impact.

2.3 Report outline

This report assesses the bibliometric performance of HRB-supported publications between 2000 and 2012. It contains a methodology (Section 3) and a full guide to bibliometric methodology (Annex 1).

The baseline bibliometric analyses (Section 4) assesses HRB-supported publications. It analyses the categorisation and share of types of publication and identifies the most frequent journals used by researchers supported by the HRB. It then analyses trends in research output, uncited and highly cited papers (papers in the world's top 10% of research by field and year of publication) and trends in citation impact. These data are brought together in an Impact Profile® comparing HRB-supported papers to benchmarks for similar Irish clinical/health/pre-clinical and biological sciences research.

The report then analyses HRB-supported papers by HRB strategic pillar areas and funding schemes (Section 5) and by *Web of Science℠* journal category (Section 6). Patterns of domestic and international co-authorship in HRB-supported papers are analysed overall and by time (Section 7).

3. Methodology

Annex 1 provides the standard methodology and data definitions used in bibliometric and citation analyses. This Section discusses bibliometrics, data sources, and summarises the methodology used in this report.

3.1 Bibliometrics and citation analysis

Research evaluation is increasingly making wider use of bibliometric data and analyses. Bibliometrics is the analysis of data derived from publications and their citations. Publication of research outcomes is an integral part of the research process and is a universal activity. Consequently, bibliometric data have a currency across subjects, time and location that is found in few other sources of research-relevant data. The use of bibliometric analysis, allied to informed review by experts, increases the objectivity of, and confidence in, evaluation.

Research publications accumulate citation counts when they are referred to by more recent publications. Citations to prior work are a normal part of publication, and reflect the value placed on a work by later researchers. Some papers get cited frequently and many remain uncited. Highly cited work is recognised as having a greater impact, and Thomson Reuters (*Evidence)* has shown that high citation rates are correlated with other qualitative evaluations of research performance, such as peer review.[2] This relationship holds true across most science and technology areas and, to a limited extent, in social sciences and even in some humanities subjects.

Indicators derived from publication and citation data should always be used with caution. Some fields publish at faster rates than others and citation rates also vary. Citation counts must be carefully normalised in order to account for such variations by field. Because citation counts naturally grow over time, it is essential to account for growth by year. Normalisation is usually done by reference to the relevant global average for the field and for the year of publication.

Bibliometric indicators have been found to be more informative for core natural sciences, especially for basic science, than they are for applied and professional areas and for social sciences. In professional areas the range of publication modes used by leading researchers is likely to be diverse, as they target a diverse, non-academic audience. In social sciences there is also a diversity of publication modes, and citation rates are typically much lower than in natural sciences.

Bibliometrics work best with large data samples. As the data are disaggregated, so the relationship weakens. Average indicator values (e.g. of citation impact) for small numbers of publications can be skewed by single outlier values. At a finer scale, when analysing the specific outcome for individual departments, the statistical relationship is rarely a sufficient guide by itself. For this reason, bibliometrics are best used in support of, but not as a substitute for, expert decision-making processes. Well-founded analyses can enable conclusions to be reached more rapidly and with greater certainty, and are therefore an aid to management and to increased confidence among stakeholders, but they cannot substitute for review by well-informed and experienced peers.

[2] *Evidence* Ltd. (2002) *Maintaining Research Excellence and Volume*: A report by Evidence Ltd to the Higher Education Funding Councils for England, Scotland and Wales and to *Universities UK*. (Adams J, *et al.)* 48pp.

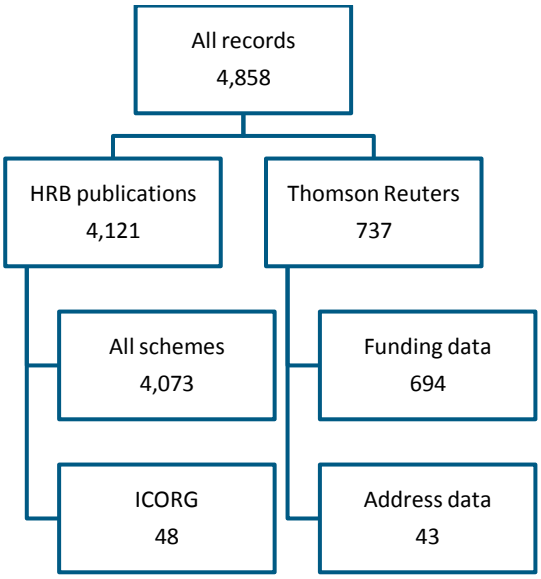
3.2 HRB publications file

The HRB supplied Thomson Reuters (*Evidence*) with its publications data captured over the last 12 years through end-of-grant reports and outputs surveys. Thomson Reuters (*Evidence*) matched these publications to the *Web of Knowledge℠*. Additional publications were found by searching the funding acknowledgement and address text using the search terms:

*((Funding Organisation OR Address = (**Health Research Board** OR **HRB**)) AND Country = **Ireland**)*

The HRB then assigned these publications to HRB unique grant numbers. The HRB publications file originally comprised 4,121 records, supplemented by an additional 737 records identified through the funding acknowledgement and address text, yielding 4,858 records in total.

Figure 3.2 HRB-supported publications



From these records, 3,502 unique publications were identified by Thomson Reuters' unique tag (UT); of these unique publications 3,382 were extracted within the database parameters used in these analyses. A total of 120 publications were not extracted; of these, 111 were outside the timeframe parameters (2000–12) and 9 were outside the citation database parameters. The HRB has fully linked these data to HRB funding schemes and, specifically, to the HRB strategic pillar areas and HRB funding schemes used in these analyses (Section 5).

3.2.1 HRB publications file composition and interpretation

Research publications typically acknowledge the source of funding that enabled the work, but this has only been indexed on a consistent basis since mid-2008. While Thomson Reuters (*Evidence*) searched the *Web of Knowledge℠* for HRB-acknowledged publications, coverage is likely to be more comprehensive after 2009 than before, as data will not have been collated to the same standard.

In addition, the HRB publications file that was used as a basis for the analysis by Thomson Reuters (*Evidence*) relied on publications data provided in end-of-grant reports and a recent HRB Outcomes Survey completed by HRB grant-holders in the 2000–09 period. The response rate for the latter survey, while just over 70% overall, was approximately 50% for grant-holders in the 2000–04 period. It should also be noted that the HRB publications file did not include publications relating to HRB grants awarded pre-2000 that may have subsequently resulted in publications in the 2000–12 period.

Both of these points would indicate that the HRB publications file is bound to be incomplete, particularly for HRB-supported publications in the 2000–04 period. Readers of this report should bear this in mind when interpreting time series and trend analyses.

3.3 Data source

For this report, bibliometric data have been sourced from Thomson Reuters databases underlying the *Web of Knowledge℠*, which gives access to journal papers, conference proceedings, patents and websites; also to chemical structures, compounds and reactions. It has a unified structure that integrates all data and search terms together and therefore provides a level of comparability not found in other databases. It is widely acknowledged to be the world's leading source of citation and bibliometric data. The *Web of Science℠* is part of the *Web of Knowledge℠* and it focuses on research published in journals and conferences in science, medicine, the arts, humanities and social sciences. The authoritative, multidisciplinary content covers over 12,000 of the highest-impact journals worldwide, including Open Access journals and over 150,000 conference proceedings. Coverage is both current and retrospective in the sciences, social sciences, the arts and humanities, in some cases dating back to 1900. Within the research community these data are often still referred to by the acronym 'ISI'. Thomson Reuters (*Evidence)* has extensive experience with databases on research inputs, activity and outputs, and it has developed innovative analytical approaches for benchmarking and interpreting international, national and institutional research impact.

The bibliometric analyses presented in this report do not cover conference proceedings, meeting abstracts, books, chapters in books or grey literature, such as reports. This report therefore captures only a specific part of the total output of HRB-supported research over the period, but this part is usually recognised as describing the most direct contribution to the research base.

3.4 Web of Science℠ journal categories

Granularity of analysis is an important issue. Unduly fine analysis at the level of research groups provides little comparability or connectedness, while coarse analysis may miss spikes of excellence in key areas.

Journals are mapped to one or more subject categories, and every article within that journal is subsequently assigned to that category. Thomson Reuters (*Evidence*) uses these categories as the basis for bibliometric analysis because they are well established and informed by extensive work with the research community since inception. Papers from prestigious, 'multidisciplinary' and general 'biomedical' journals such as *Nature*, *Science*, *BMJ*, *The Lancet*, *New England Journal of Medicine* and the *Proceedings of the National Academy of Sciences* (*PNAS*) are assigned to specific categories based on the journal categories of the citing and cited references in each article. Further information about the journals included in the citation databases, and how they are selected, is available here: http://scientific.thomsonreuters.com/mjl/.

3.5 Definitions

Papers/publications:

Thomson Reuters abstracts publications, including editorials, meeting abstracts and book reviews and research journal articles. The terms 'paper' and 'publication' are often used interchangeably to refer to printed and electronic outputs of many types. In these analyses the term 'paper' has been used exclusively to refer to substantive journal articles, reviews and some proceedings papers, and it excludes editorials, meeting abstracts or other types of publication. Papers are the subset of publications for which citation data are most informative and which are used in calculations of citation impact.

Citations:

The citation count is the number of times that a citation has been recorded for a given publication since it was published. Not all citations are necessarily recorded, since not all publications are indexed. However, the material indexed by Thomson Reuters is estimated to attract about 95% of global citations.

Citation impact:

'Citations per paper' is an index of academic or research impact (as compared with economic or social impact). It is calculated by dividing the sum of citations by the total number of papers in any given dataset (so, for a single paper, raw impact is the same as its citation count). Impact can be calculated for papers within a specific research field such as clinical neurology, for a specific institution or group of institutions, or for a specific country. Citation count declines in the most recent years of any time period, as papers have had less time to accumulate citations (papers published in 2007 will typically have more citations than papers published in 2012).

Field-normalised citation impact (nci_F):

Citation rates vary between research fields and with time. Consequently, analyses must take both field and year into account. In addition, the type of publication will influence the citation count. For this reason, only citation counts of papers (as defined above) are used in calculations of citation impact. The standard normalisation factor is the world average number of citations per paper for the year and journal category in which the paper was published. This normalisation is also referred to as 'rebasing' the citation count.

Mean normalised citation impact (mnci):

The mean nci indicator for any specific dataset is calculated as the mean of the field-normalised citation impact (nci_F) of all papers within that dataset.

Journal impact factor (JIF):

In the same way that citation impact can be used as an index of research quality, the average number of citations per paper can be used to indicate the impact and/or importance of a journal. The impact factor for a journal (JIF) is calculated using data for a three-year period. For example, the 2012 impact factor for a given journal is calculated by Thomson Reuters as the average number of times that articles from the journal published in the past two years (2010 and 2011) were cited in 2012. Thus, a JIF of 2.0 means that, on average, the articles published in 2010 or 2011 have been cited twice. Citing articles may be from the same journal; however, most citing articles are from other journals.

For the journal *Infection and Immunity*, the 2012 journal impact factor would be calculated as follows:

Cites in 2012 to items published in 2011 =	1,950	Number of items published in 2011 =	506
Cites in 2012 to items published in 2010 =	2,283	Number of items published in 2010 =	533
Total	**4,233**		**1,039**

$$\frac{Number\ of\ citations}{Number\ of\ \text{items}} = \frac{4{,}233}{1{,}039} = \mathbf{4.074}$$

The calculation of the journal impact factor is fully described on the Thomson Reuters website at: http://thomsonreuters.com/products_services/science/free/essays/impact_factor/.

When looking at journal impact factor data it is important to remember that, as citation rates vary between research fields and publication type, these will affect the JIF. For example, a JIF of 4.074 ranks the journal *Infection and Immunity* 13th out of 69 journals in the Infectious Diseases *Web of Science℠* journal category and therefore in the first quartile (Q1). However, the same journal is ranked 34th out of 134 journals in the *Web of Science℠* journal category of Immunology and therefore in the second quartile (Q2). The tables in this report use the highest quartile of the journal where it has multiple *Web of Science℠* journal categories. In this example, the quartile shown for *Infection and Immunity* would be Q1.

3.6 Interpretation of data and analyses

Papers: The minimum number of papers suitable as a sample for quantitative research evaluation is a subject of widespread discussion. Larger samples are always more reliable, but a very high minimum may defeat the scope and specificity of analysis. Experience has indicated that a threshold between 20 and 50 papers can generally be deemed appropriate. For work that is likely to be published with little contextual information, the upper boundary (≥ 50) is a desirable starting point. For work that will be used primarily by an expert, in-house group, then the lower boundary (≥ 20) may be approached. Because comparisons for in-house evaluation often involve smaller, more specific research groups (compared to broad institutional comparisons) a high volume threshold is self-defeating. Smaller samples may be used, but outcomes must be interpreted with caution, and expert review should draw on multiple information sources before reaching any conclusions.

Mean field normalised citation impact: nci_F values for individual papers vary widely and it is more useful to consider the mean nci_F. This average can be at several granularities: field (either journal category or field), annual and overall (total output under consideration). When considering such mean nci_F data points, care must be taken to understand that these data are highly skewed, and the average can be driven by a single, highly cited paper (this would be highlighted in accompanying text but would not be apparent from tables and figures). The world average is 1.0, so any nci_F value higher than this indicates a paper, or set of papers, which are cited more than average for similar research worldwide. For research management purposes, experience suggests that nci_F values between 1.0 and 2.0 should be considered to be indicative of research which is influential at a national level, while that cited more than twice the world average has international recognition.

Research field: A problem frequently encountered in the analysis of data about the research process is that of 'mapping'. For example, a funding body allocates money for chemistry, but this goes to researchers in biology and engineering as well as to chemistry departments. Clinicians publish in

mathematics and education journals. Publications in environmental journals come from a diversity of disciplines. This creates a problem when we try to define, for example, 'parasitology research'. Is this the work funded under parasitology programmes, the work of researchers in parasitology units or the work published in parasitology journals? For the first two options we need to track individual grants and researchers to their outputs, which is feasible but not within the scope of this study nor for every comparator institution. Therefore, to create a simple and transparent dataset of equal validity across time and geography, we rely on the set of journals associated with parasitology as a proxy for the body of research reflecting the field.

Benchmarks comprise 'Clinical and Health and 'Pre-clinical' and 'Biological Sciences' research, and has been defined through in-house mapping of *Web of Knowledge℠* journal categories.

Indicator values:

Indicator	Threshold
Number of publications (all output types)	No threshold.
Number of papers (articles and reviews)	Citation analyses (impact, mnci) based on fewer than 20 papers at any particular aggregation, e.g. year or field are not reliable.
Percentage of highly cited papers (those ranked in the top decile of world papers relative to field/journal category and year)	A value of more than 10% indicates better than world average. However, the benchmark will be different for different countries: Irish clinical and health and pre-clinical research (13.0%) Irish biological sciences research (15.5%)
Mean normalised citation impact data (an indication of paper quality within the field)	A value of more than 1.0 indicates better than the world average. For individual countries, the benchmark will be different. For Ireland, the relevant benchmarks are: Irish clinical/health/pre-clinical research (1.20) Irish biological sciences research (1.29)[3]

[3] UK benchmarks are not used in this report, as data for the UK are derived from the UK National Citation Report 2003-12, which differs from the time period used in these analyses (2000–12). However, the equivalent UK and Irish benchmarks for the 2003–12 period are:

Clinical/health/pre-clinical research: UK (1.36), Ireland (1.24)
Biological sciences research: UK (1.39), Ireland (1.29)

The overall citation impact of HRB-supported research over the same period is, by some margin, higher than these benchmarks (1.74).

4. Baseline bibliometric analyses

This section of the report analyses the HRB publications file in terms of number of publications, and papers used in citation analyses between 2000 and 2012. It examines whether HRB-supported papers have been published in high-impact journals, and the performance of these papers compared to selected benchmarks for similar Irish clinical/health/pre-clinical and biological sciences research.

HRB-supported researchers have published papers, which overall have a higher than average citation impact (1.74), and have published in high-impact journals. Subject to important caveats set out in Section 3.2.1 regarding the composition of the HRB publications file, HRB-supported papers have grown in volume, making an increasing contribution to the overall level of Irish clinical/health/pre-clinical and biological sciences research. HRB-supported papers have performed excellently, both absolutely and relative to benchmarks for similar Irish clinical/health/pre-clinical and biological sciences research.

Key findings

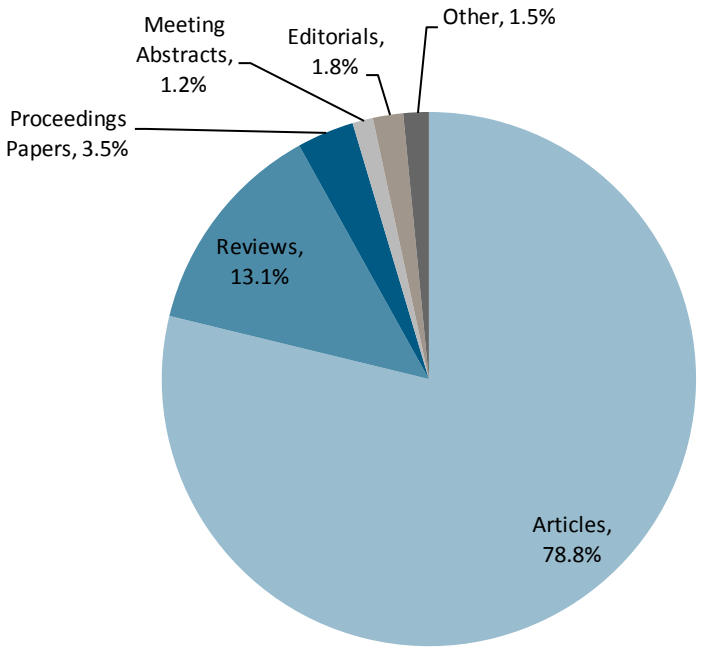
- The HRB publications file contains 3,382 publications of which 95.4% (3,226) are papers used in citation analyses (Section 4.1). These papers have been published in over 1,000 journals (1,088), which is highly dispersed, indicating a diverse research portfolio (Section 4.2).
- The vast majority (86.0%) of HRB-supported papers have been published in journals in the highest quartiles of journals by journal impact factor. Over half of HRB-supported papers (53.4%) have been published in the world's top 10% of journals.
- The top three journals of HRB-supported papers by volume are all in the top quartile of journals by journal impact factor (*Journal of Biological Chemistry*, *PloS One* and *Journal of Immunology*). HRB-supported researchers have published in high-impact journals such as the *New England Journal of Medicine, The Lancet*, *Nature* (multiple titles) and *Science*.
- Subject to caveats set out in Section 3.2.1, HRB-supported papers have grown rapidly, from 317 papers (2000–04) to 2,247 papers (2008–12), (Section 0). Growth in HRB-supported papers appears to have been faster than Irish growth in clinical/health/pre-clinical and biological sciences research. HRB-supported papers have made a growing contribution to Irish research output in these fields.
- Some 14.7% of HRB-supported papers are uncited, but, as expected, most of these were published recently (2010–12). Prior to this, only 27 HRB-supported papers are uncited, suggesting high research uptake and use.
- Around one-fifth (18.9%) of HRB-supported papers are in the world's top 10% of research. This is nearly twice the world average (Section 0). However, the percentage of HRB-supported papers in the world's top 10% has fallen from 24.3% (2000–04) to 18.2% (2008–12). In contrast, the citation impact of HRB-supported papers has risen from 1.58 (2000–04) to 1.84 (2008–12), (Section 4.6). HRB-supported papers in the earliest five-year period (2000–04) were small in volume, but with high citation impact. This is less likely to reflect a 'fall' in research quality, than a 'stabilisation' as papers increase.
- The Impact Profile® of HRB-supported papers outperforms the benchmarks for similar Irish clinical/health/pre-clinical and biological sciences research. Furthermore, the high citation impact of HRB-supported papers is not limited to a small number of papers, but to a sustained publishing pattern across the HRB research portfolio (Section 4.7).

- On balance, HRB-supported papers have increased and the citation impact of these papers is high and rising. Furthermore, while the percentage of its papers in the world's top 10% has fallen, it is still around twice the world average.

4.1 Categorisation and share of types of publication

Articles, reviews and peer-reviewed proceedings papers published in peer-reviewed journals (papers) are the publication types for which citation data are most informative and which are used in calculations of citation impact. Citation analyses do not cover conference proceedings, meeting abstracts, books, chapters in books or grey literature, such as reports. These analyses therefore capture only a specific part of the total research output over the period, but this part is usually recognised as describing the most direct contribution to the research base.

Figure 4.1 Categorisation and share of HRB-supported publications by document type, 2000–12



Data & analysis: Thomson Reuters (*Evidence*)

The HRB publications file contains 3,382 publications. Of these, 95.4% are papers (3,226) used in citation analyses in this report. As only papers were searched in the funding acknowledgement, and address data on the Thomson Reuters *Web of Knowledge*℠, these proportions reflect the HRB publications file captured in these analyses.

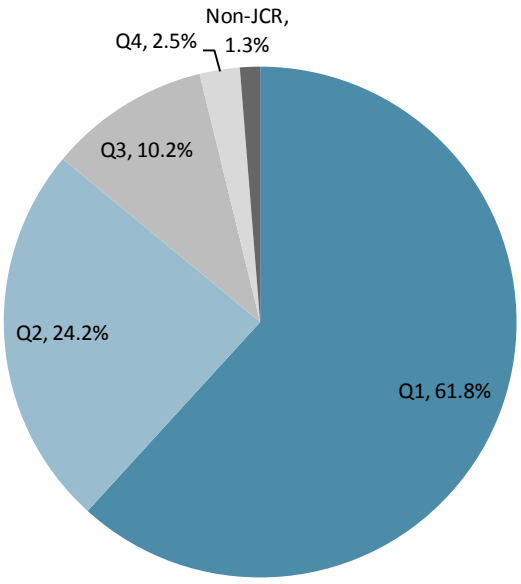
4.2 Journal usage

HRB-supported researchers have published in high-impact journals.

The JIF provides an indicator of the impact and/or importance of a journal. The JIF is useful for indicating whether researchers are publishing their work in journals with the highest impact in a particular field. It should be noted, however, that the highest-impact journals in a given journal category may not always be the most appropriate location for the publication of a particular paper. For example, a paper relating to a small specialist area might be more visible to other interested researchers in a less well-cited specialist journal than in a more highly cited journal with a broader disciplinary focus. The JIF and quartile data presented here are sourced from the Thomson Reuters *Journal Citation Report* 2012, with further technical information provided in Section 3.5.

The 3,226 HRB-supported papers in these analyses have been published in 1,088 journals. HRB-supported papers have been highly dispersed over these journals, using a measure of dispersion (0.93). A value of 0 indicates that only one journal is represented in the dataset. The closer the value to 1, the more dispersed the set of papers. The HRB publications file is very diverse compared to other studies conducted by Thomson Reuters (*Evidence*). The vast majority (86.0%) of HRB-supported papers have been published in journals in the highest quartiles (Q1 and Q2), (Figure 4.2). Over half (53.4%) of HRB-supported papers have been published in the world's top 10% of journals by JIF.

Figure 4.2 Proportion of HRB-supported papers published in journals by journal impact factor quartile, 2000–12



Data & analysis: Thomson Reuters (*Evidence*)

The top three journals containing HRB-supported papers by volume are all in the top quartile (Q1) of journals by JIF. These are the *Journal of Biological Chemistry* (86 papers), *PloS One* (44 papers) and the *Journal of Immunology* (41 papers). The *Irish Journal of Medical Science* has a low JIF (0.506) and is in the lowest quartile of journals by JIF (Q4), (Table 4.2.1). This is joint fourth with the *Cochrane Database of Systematic Reviews* in terms of usage.

The *New England Journal of Medicine* has the highest JIF (51.658); nine HRB-supported papers have been published there. HRB-supported researchers have also published in other high-impact journals such as *The Lancet*, *Nature* (multiple titles) and *Science*, (Table 4.2.2).

Table 4.2.1 HRB-supported papers by journal and JIF, 2000–12 (by volume)

Journal	Papers	JIF	Quartile
Journal of Biological Chemistry	86	4.651	Q1
PLoS One	44	3.73	Q1
Journal of Immunology	41	5.52	Q1
Cochrane Database of Systematic Reviews	29	5.703	Q1
Irish Journal of Medical Science	29	0.506	Q4
Biochemical Society Transactions	26	2.587	Q3
British Journal of Cancer	24	5.082	Q1
Biochemical and Biophysical Research Communications	22	2.406	Q3
British Journal of Pharmacology	20	5.067	Q1
Infection and Immunity	20	4.074	Q1
Microbiology	19	2.852	Q2
International Journal of Cancer	18	6.198	Q1
Proceedings of the National Academy of Sciences of the USA	18	9.737	Q1
Advances in Experimental Medicine and Biology	17	1.825	Q2
Gut	17	10.732	Q1
Journal of Advanced Nursing	17	1.527	Q1
American Journal of Medical Genetics Part B-Neuropsychiatric Genetics	16	3.231	Q2
Journal of Neurochemistry	16	3.973	Q2
Neurobiology of Aging	15	6.166	Q1

Table 4.2.2 HRB-supported papers by journal and journal impact factor, 2000–12 (by JIF)

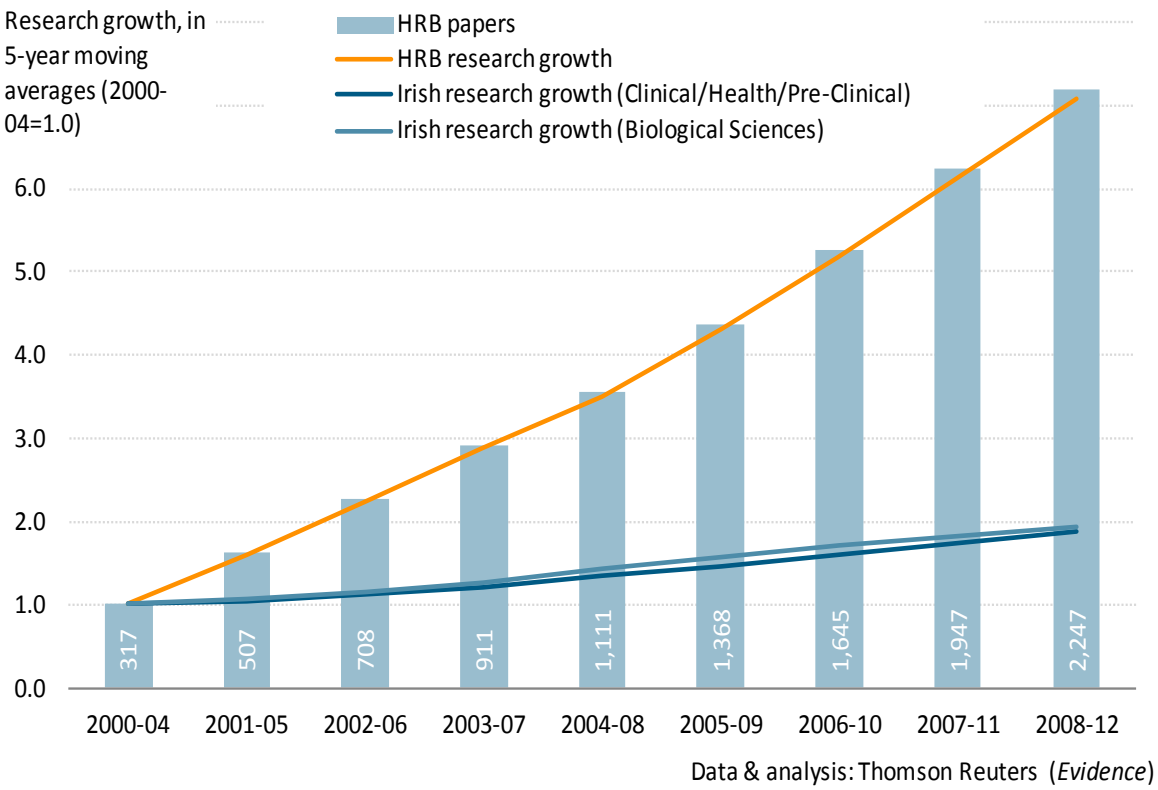
Journal	Papers	JIF	Quartile
New England Journal of Medicine	9	51.658	Q1
The Lancet	4	39.06	Q1
Nature	5	38.597	Q1
Nature Genetics	10	35.209	Q1
Nature Reviews Cancer	4	35	Q1
Nature Reviews Immunology	6	33.129	Q1
Nature Reviews Drug Discovery	1	33.078	Q1
Science	1	31.027	Q1
JAMA (The Journal of the American Medical Association)	1	29.978	Q1
Progress in Polymer Science	1	26.383	Q1
Nature Immunology	6	26.199	Q1

Journal	Papers	JIF	Quartile
Annual Review of Pathology: Mechanisms of Disease	1	25.794	Q1
Cell Stem Cell	1	25.315	Q1
The Lancet Oncology	5	25.117	Q1
The Lancet Neurology	4	23.917	Q1
Nature Medicine	3	22.864	Q1
Nature Reviews Microbiology	4	22.49	Q1
The Lancet Infectious Diseases	1	19.966	Q1
Immunity	5	19.795	Q1

4.3 Trends in research output

Subject to the important caveats set out in Section 3.2.1 regarding the composition of the HRB publications file, HRB-supported papers have grown rapidly (Figure 0.1). Between 2002 and 2007, the HRB annual budget and value of funding commitments rose sharply as a result of increased governmental support for science, technology and innovation programmes. It appears that growth in HRB-supported papers has been higher than overall Irish growth in clinical/health/pre-clinical and biological sciences research. 'Relative growth' in output can be assessed by indexing research output to a start year, which becomes 1.0, and then working forwards. Between 2000 and 2004, HRB-supported researchers produced 317 papers (1.0), as captured by the HRB publications file. Between 2008 and 2012, HRB-supported researchers produced 2,247 papers (index on 2000–04 = 7.09). This estimate needs to be interpreted with an awareness that growth may be lower than this, given data capture prior to 2008. Irish research growth in clinical/health/pre-clinical research has almost doubled (index on 2000–04 = 1.87) from 8,127 papers (2000–04) to 15,160 papers (2008–12). Irish research growth in biological sciences has also almost doubled (index on 2000–04 = 1.92) from 3,594 papers (2000–04) to 6,907 papers (2008–12).

Figure 4.3.1 HRB-supported papers and growth compared to Irish clinical/health/pre-clinical and biological sciences research, 2000–12

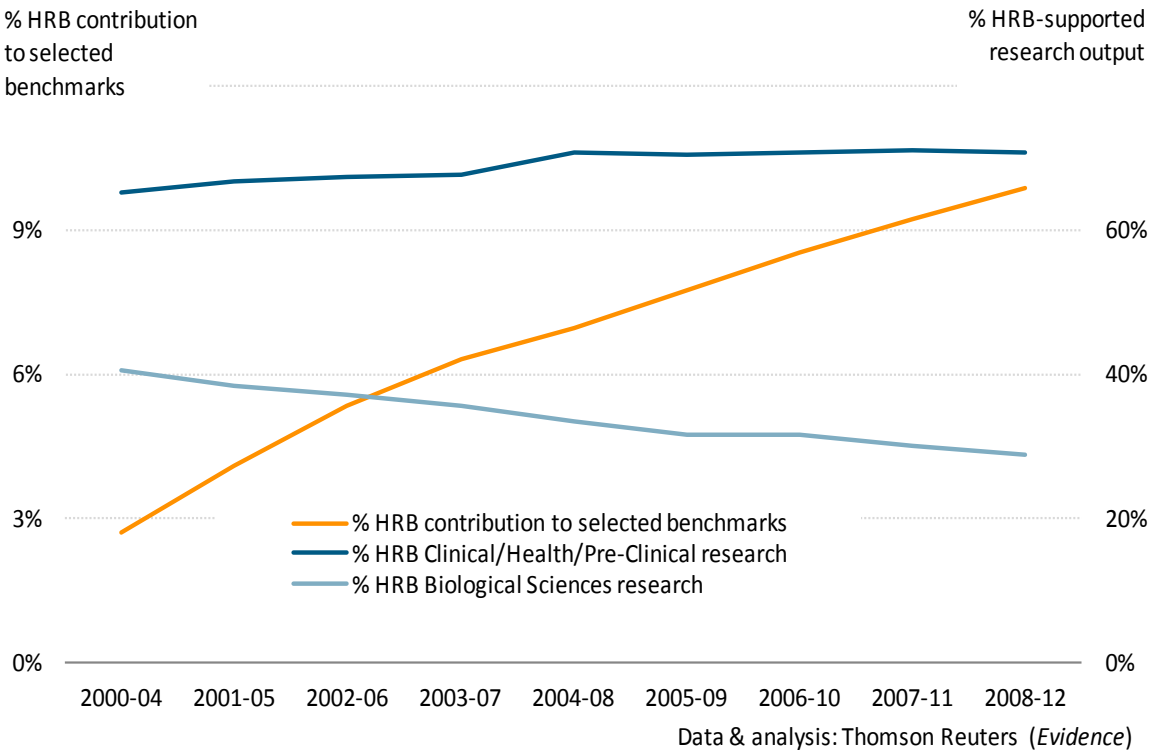


Notwithstanding the important caveats outlined above, it is clear that there has been growth in HRB-supported papers and it is likely to have been much higher than Irish research growth in clinical/health/pre-clinical and biological sciences research.

Some 2,960 HRB-supported papers match the combined benchmarks for Irish clinical/health/pre-clinical and biological sciences research selected for this report (91.8%). Figure 0.2 shows that HRB-supported papers have contributed to a growing share of Irish clinical/health/pre-clinical and biological sciences research –around 10% by 2008–12.

While the proportion of HRB-supported papers in biological sciences has decreased from 40.7% (2000–04) to 28.9% (2008–12), the proportion of HRB-supported papers in clinical/health/pre-clinical research has increased from 65.3% (2000–04) to 70.6% (2008–12).

Figure 4.3.2 Contribution of HRB-supported papers to Irish clinical/health/pre-clinical and biological sciences research, and as a percentage of HRB-supported papers, 2000–12



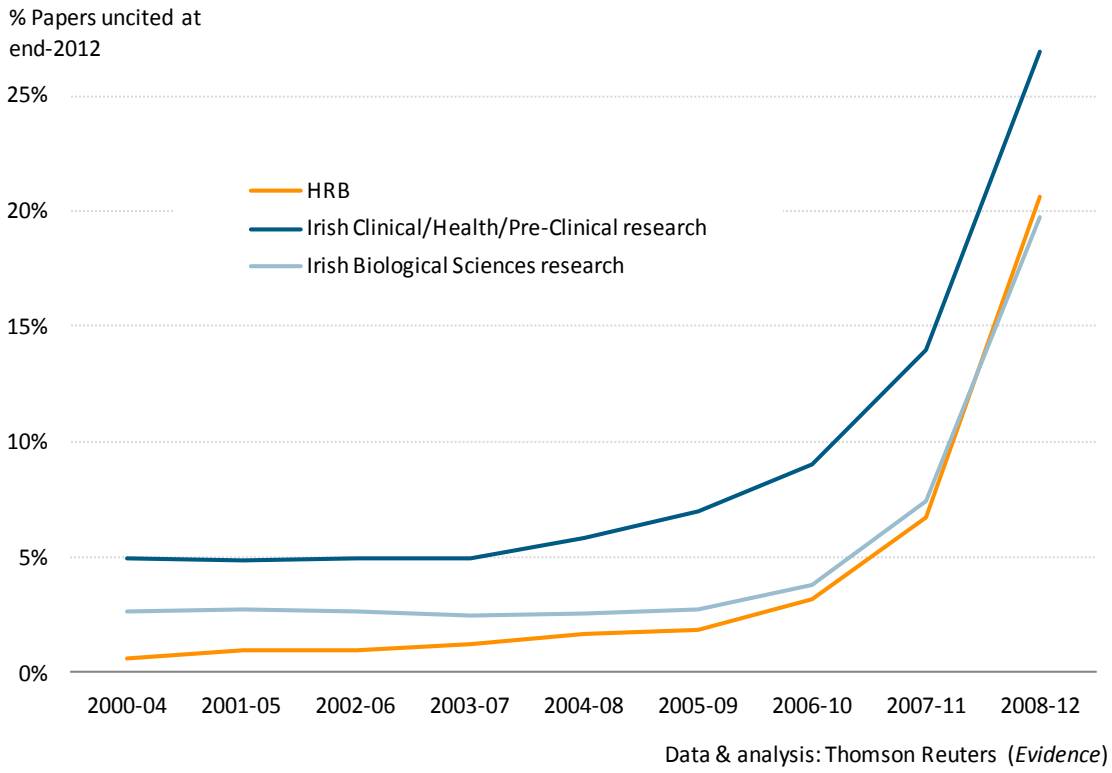
4.4 Uncited papers

Papers can remain uncited for many different reasons. This may be because their content is of little or no importance, but that is not the only reason. Other reasons include, but are not limited to:

- The paper has been published in a journal not read by researchers to whom it might be interesting.
- The paper presents important but 'negative' work reporting a blind alley to be avoided by others.
- The work is a 'sleeping beauty' that has yet to be recognised for its significance.

Bibliometrics do not indicate why a given paper is uncited and therefore this indicator should be interpreted with care.

Figure 4.4 Percentage of HRB-supported papers uncited at end-2012 compared to benchmarks for Irish clinical/health/pre-clinical and biological sciences research, 2000–12



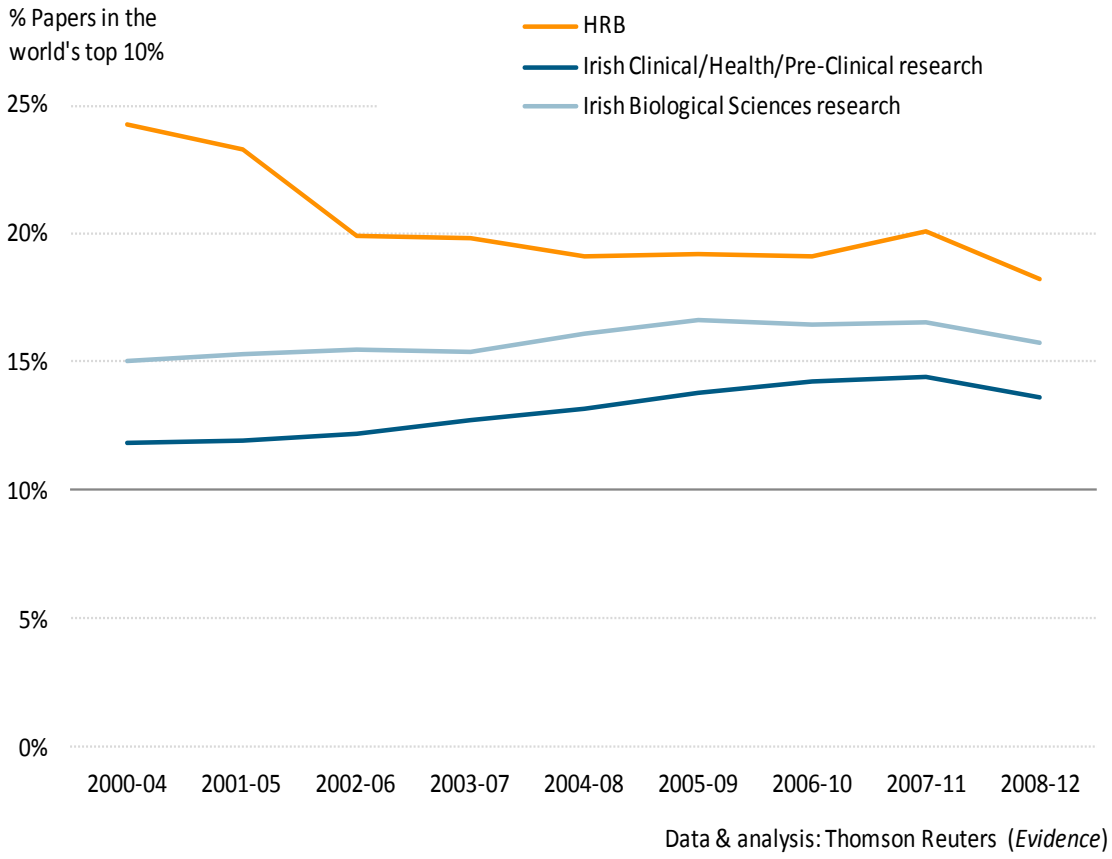
While there has been a sharp increase in uncited papers in more recent years (see 'Time Factors' in Annex 1), HRB-supported papers are more likely to be cited than Irish clinical/health/pre-clinical research papers (14.7% of HRB papers uncited compared to 16.3%), (Figure 4.4). The pattern of uncited HRB-supported papers is similar to that of Irish biological sciences research. Prior to 2010, only 27 HRB-supported papers out of 1,685 papers were uncited at end-2012 (1.6%). This suggests a high uptake and use of HRB-supported papers.

4.5 Highly cited papers

Highly cited work is generally recognised as having a greater impact and is correlated with other qualitative evaluations of research performance, such as peer review. But there are some papers that are frequently cited because their significance is slightly different: they describe key methodology; they are a thoughtful and wide-ranging review of a field; or they represent contentious views which others seek to refute. Citation analysis cannot make value judgments about why an article is highly cited.

In this section, 'highly cited' papers are defined as those in the world's top 10% of research for field and year of publication.

Figure 4.5 HRB-supported papers in the world's top 10% of research compared to benchmarks for Irish clinical/health/pre-clinical and biological sciences research, 2000–12



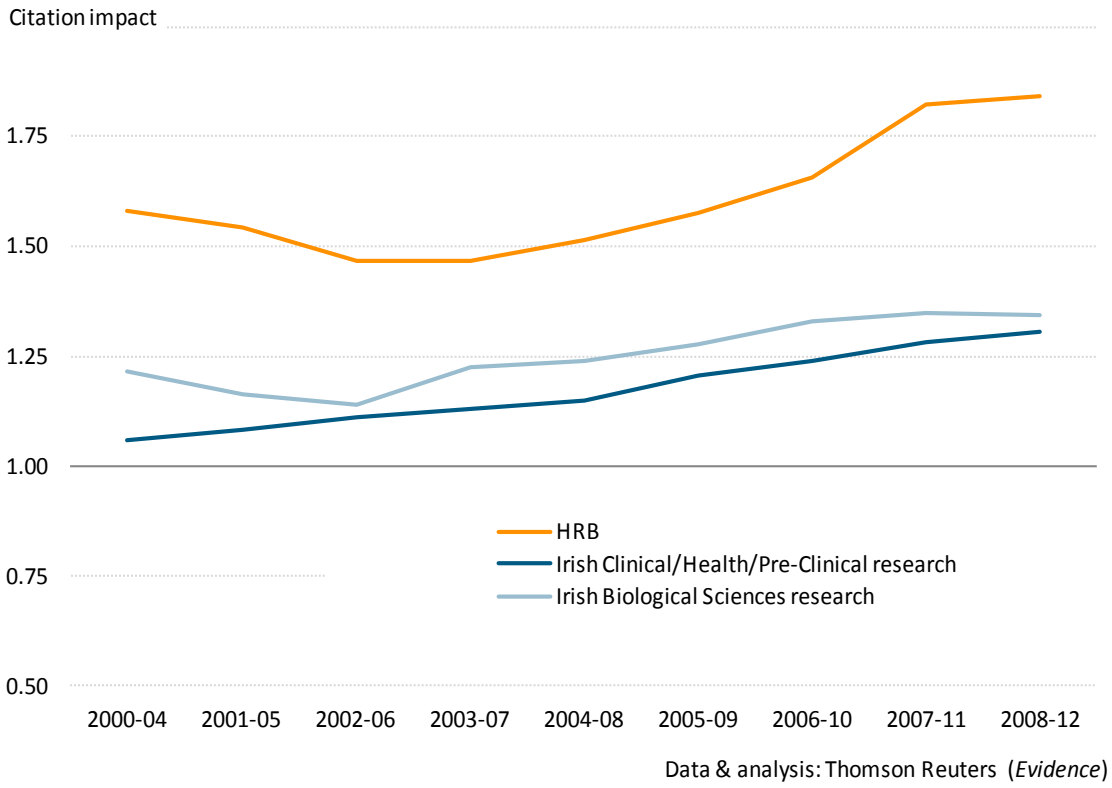
While Figure 0 shows that the percentage of HRB-supported papers in the top 10% worldwide has fallen, it also shows that broadly over time, around one-fifth (18.9%) of HRB-supported papers are in the top 10% worldwide, i.e. around twice the world average. Furthermore, this is higher than the benchmarks for Irish clinical/health/pre-clinical research (13.0%), and biological sciences research (15.5%).

However, the trends are in opposite directions. The percentage of HRB-supported papers in the world's top 10% has fallen from 24.3% (2000–04) to 18.2% (2008–12). In contrast, the percentage has risen for Irish clinical/health/pre-clinical research from 11.9% (2000–04) to 13.6% (2008–12); Irish biological sciences research has risen from 15.1% (2000–04) to 15.7% (2008–12).

4.6 Citation impact

In contrast to Figure 0, the citation impact of HRB-supported papers is not only well over the world average (1.74), but it has also risen from 1.58 (2000–04) to 1.84 (2008–12) despite a drop in the earlier part of the last decade (Figure 4.6). This drop may relate to small paper numbers or it may parallel trends in Irish biological sciences research, as the pattern is similar. Citation impact is much higher than the benchmark for Irish clinical/health/pre-clinical research (1.20) and Irish biological sciences research (1.29).

Figure 4.6 Citation impact of HRB-supported papers compared to benchmarks for Irish clinical/health/pre-clinical and biological sciences research, 2000–12



There are several factors that may explain the differences between the trends observed in Figures 0 and Section 4.6.

Firstly, the distribution of citations amongst papers is highly skewed because some papers accumulate very large citation counts. This may suggest that HRB-supported researchers have been involved in some high-impact research which can increase the average measure (citation impact) rather than the percentile measure (papers in the top 10% worldwide).

Secondly, HRB-supported paper numbers were smaller at the beginning of the 2000s than in the later part of that decade, given the growth in HRB-supported papers (Section 0). Papers with high citations per paper, even when normalised, have a greater effect on smaller rather than larger samples. Therefore, apparent falls in citation impact or proportion of papers in the world's top 10% of

research in the earlier part of the last decade might relate to 'stabilisation' associated with growing paper numbers.

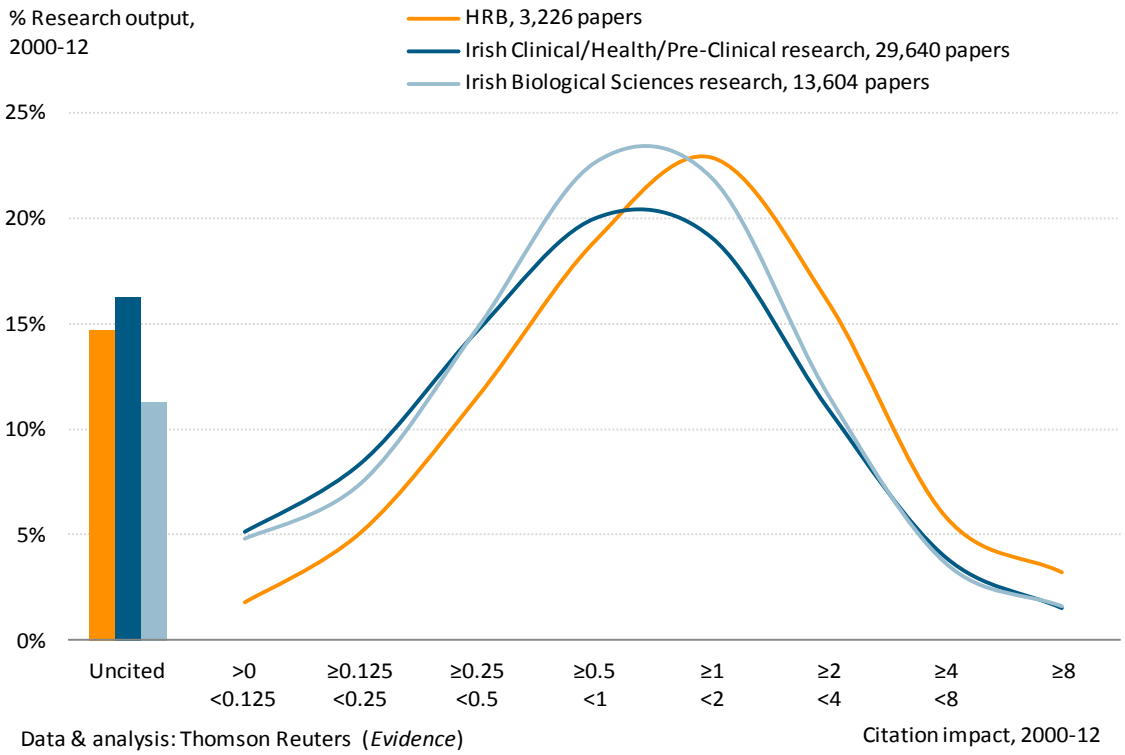
On balance, however, HRB-supported papers have shown extraordinary growth, and the citation impact of these papers is high and rising. While the percentage of HRB-supported papers in the world's top 10% has fallen, it is still well over the world average.

4.7 Impact Profile®

The Impact Profile® (Figure 4.7) shows that HRB-supported papers outperform benchmarks for similar research in Ireland.

Thomson Reuters (*Evidence*) has developed a bibliometric methodology[4] which shows the proportion of papers that are uncited and the proportion that lie in each of eight categories of relative citation rates, normalised (rebased) to world average. An Impact Profile® enables an examination and analysis of the strengths and weaknesses of published outputs relative to world average and relative to a reference profile. This provides much more information about the basis and structure of research performance than conventionally reported averages in citation indices.

Figure 4.7 Impact Profile® of HRB-supported papers compared to Irish clinical/health/pre-clinical and biological sciences research, 2000–12



[4] Adams J, Gurney K and Marshall S (2007) Profiling citation impact: A new methodology. *Scientometrics* **72**: 325-344.

Fewer HRB-supported papers are uncited compared to the benchmark for clinical/health/pre-clinical research (14.7% compared to 16.3%), whereas more HRB-supported papers are uncited compared to the benchmark for Irish biological sciences research (11.3%), (Section 4.4). However, the distribution of citation impact across the Impact Profile® categories is different, particularly in the categories of higher citation impact.

Some 47.9% of HRB-supported papers are cited more than the world average. Some 37.4% are cited less than the world average. Therefore, the HRB Impact Profile® is right-shifted towards the categories of higher citation impact. In contrast, the Impact Profiles® are left-shifted towards the categories of lower citation impact for Irish clinical/health/pre-clinical research and Irish biological sciences research. In the Impact Profile® categories of the highest citation impact (≥4), HRB-supported papers outperform the selected Irish benchmarks. Some 9.1% of HRB-supported papers are cited at least four times or more than the world average. This compares to 5.5% of Irish clinical/health/pre-clinical research and 5.3% of Irish biological sciences research.

5. HRB strategic pillar areas and funding schemes

This section of the report analyses the performance of HRB-supported papers by HRB strategic pillar areas (Biomedical, Clinical and Population Health and Health Services research) and HRB funding schemes, between 2000 and 2012. Data for 'Health Services Research' and 'Population Health Sciences' have been combined into 'Population Health and Health Services research' for the purposes of this report.

In the future, HRB investment will increasingly focus on patient-oriented research, as well as health services and population health sciences research. The aim is to speed up the translation of research innovations and discoveries into real benefits for patients and the public, closing the gap between research outcomes and their application in policy, practice and health service delivery.[5]

Key findings

- Over two-thirds of HRB-supported papers are related to the Biomedical strategic pillar area, although the proportion of Clinical (one fifth of HRB-supported papers) and Population Health and Health Services research (over a tenth of HRB-supported papers) has been growing.
- HRB-supported Clinical papers have a very high citation impact – over twice the world average (2.20). This is internationally significant research.
- HRB-supported Biomedical papers are also well cited (1.67), and given HRB's historical focus on biomedical research, the citation impact is similar to overall HRB-supported papers (1.74).
- The citation impact of HRB-supported Population Health and Health Services papers is increasing and is now approaching one a half times greater than the world average (1.47, 2008–12).
- Some HRB funding schemes have exceptionally high citation impact (Section 5.2). Papers associated with Infrastructure and Special Initiatives schemes are cited over four times the world average (4.07). The papers of the Cancer Consortium (particularly the ICORG Cancer Clinical Trials Network) are also cited nearly four times the world average (3.96).
- HRB-funding schemes relating to career development are also very well cited; such schemes include the Clinician Scientist Award, Post-Doctoral Fellowships, PhD Scholars Programme and Medical-AHP Fellowships. These are cited around or over twice the world average.
- Programmes and Projects (the largest aggregations of funding schemes) are also well cited (1.56 and 1.46, respectively) although other funding schemes are driving higher citation impact.

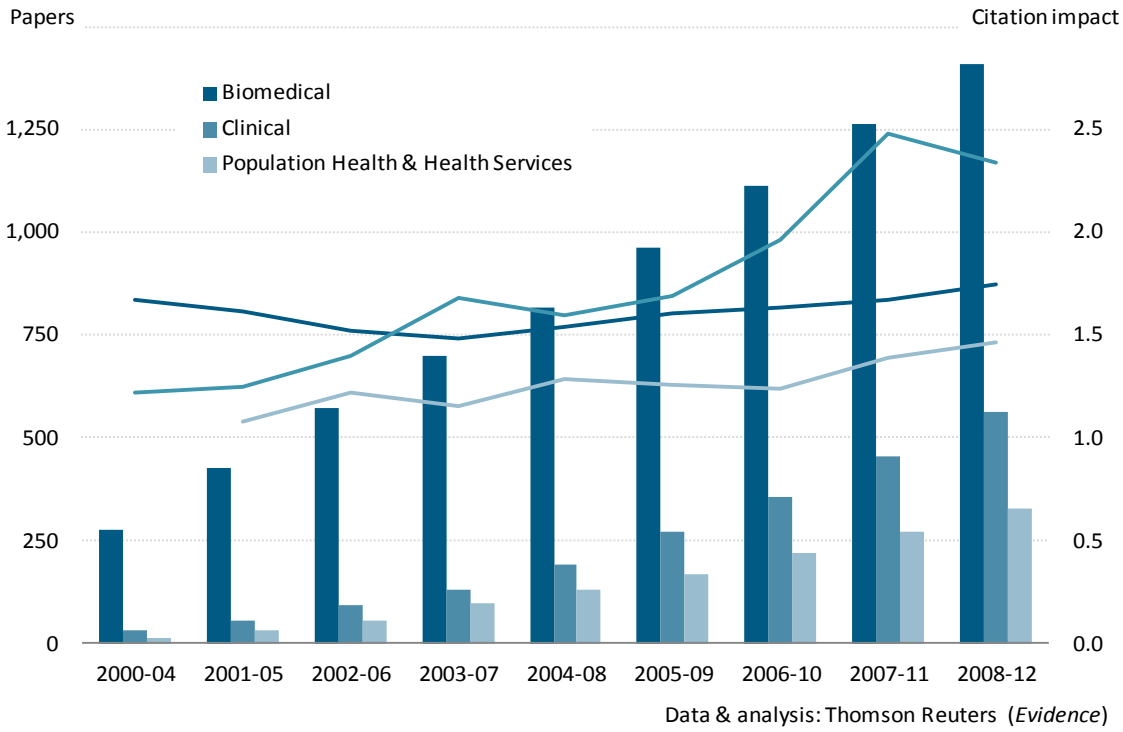
[5] http://www.hrb.ie/research-strategy-funding/

5.1 HRB strategic pillar areas

Two-thirds of HRB-supported papers (67.2%) are related to the Biomedical strategic research pillar (2,169 papers). The numbers have grown from 276 (2000–04) to 1,406 (2008–12), representing more than a five-fold growth (5.09). One-fifth of HRB-supported papers (21.6%) are related to the Clinical strategic pillar area (697 papers). This has grown from 30 papers (2000–04) to 561 papers (2008-12). Over one-tenth (13.1%, 422 papers) are related to Population Health and Health Services papers. This has grown from 13 papers (2000–04) to 327 papers (2008–12). These growth figures are subject to the caveats set out in Section 3.2.1.

Figure 5.1 HRB-supported papers and citation impact by HRB strategic pillar area, 2000–12

Citation impact data for Population Health and Health Services papers (2000-04) is not shown, as it relates to <20 papers.



The overall citation impact of HRB-supported papers is 1.74 (Section 4.6). HRB-supported Biomedical papers show similar trends to overall HRB-supported papers (Figure 5.1), although citation impact is slightly (but not notably) lower in aggregate (1.67).

The Clinical strategic pillar area has the highest citation impact: over twice the world average (2.20). The citation impact of HRB-supported Population Health and Health Services papers is increasing, and is approaching one and a half times greater than the world average (1.47, 2008–12). Overall, its citation impact is well above the world average (1.40), although this is lower than the citation impact for HRB-supported papers overall (1.74).

5.2 HRB funding schemes and grant types

Figure 5.2 shows the performance of HRB-supported papers by HRB funding schemes and grant types. Full data for all funding schemes is provided in Table 5.2. In order of citation impact:

- The papers of two funding schemes (**Infrastructure** and **Special Initiatives**) are cited over four times the world average (4.07).
  - Grant types with high citation impact associated with Infrastructure schemes includes the Clinical Research Facility (4.72), Equipment (2.89) and also the Health Information System (8.03) although the latter is based on a small number of papers (13).
  - Funding schemes associated with 'Special Initiatives' are associated with a small number of papers, but the papers of the Autism Genome Project and ELDERMET are well cited.
- Papers associated with the **Cancer Consortium** are cited nearly four times the world average (3.96). The papers associated with the ICORG Cancer Clinical Trials Network are cited nearly seven times the world average (6.82).
- The papers associated with the **Clinician Scientist Award** funding scheme are cited over three times the world average (3.36).
- The papers associated with **Post-Doctoral Fellowships**, **PhD Scholars Programme** and **Medical-Allied Health Professionals (AHP) Fellowships** are cited around or over twice the world average.
  - For Medical-AHP Fellowships, performance is driven by the Health Professionals Fellowship (2.65) funding scheme in particular.
- **Programmes** (1.56) is the second largest HRB grant type, and comprises mainly Programme Grants (284 papers) and the Translational Research Programmes (127 papers). These include well-cited papers, although below the average citation impact for HRB-supported papers.
- **Projects** (the largest HRB grant type) accounts for 1,661 papers and citation impact is 1.46. This again is well cited, although below the average citation impact for HRB-supported papers. This category comprises mostly the Research Project Grants scheme (1,528). This category is not shown to scale in Figure 5.2.
- The papers associated with the **Health Research Award** (1.40) and **Medical Research Charities Group** (1.25) funding schemes are well cited, although below the average citation impact for HRB-supported papers. The papers associated with the **Health Research Centre** funding scheme are cited around the world average (1.07).

Figure 5.2 HRB-supported papers and citation impact by aggregated HRB funding scheme, 2000–12

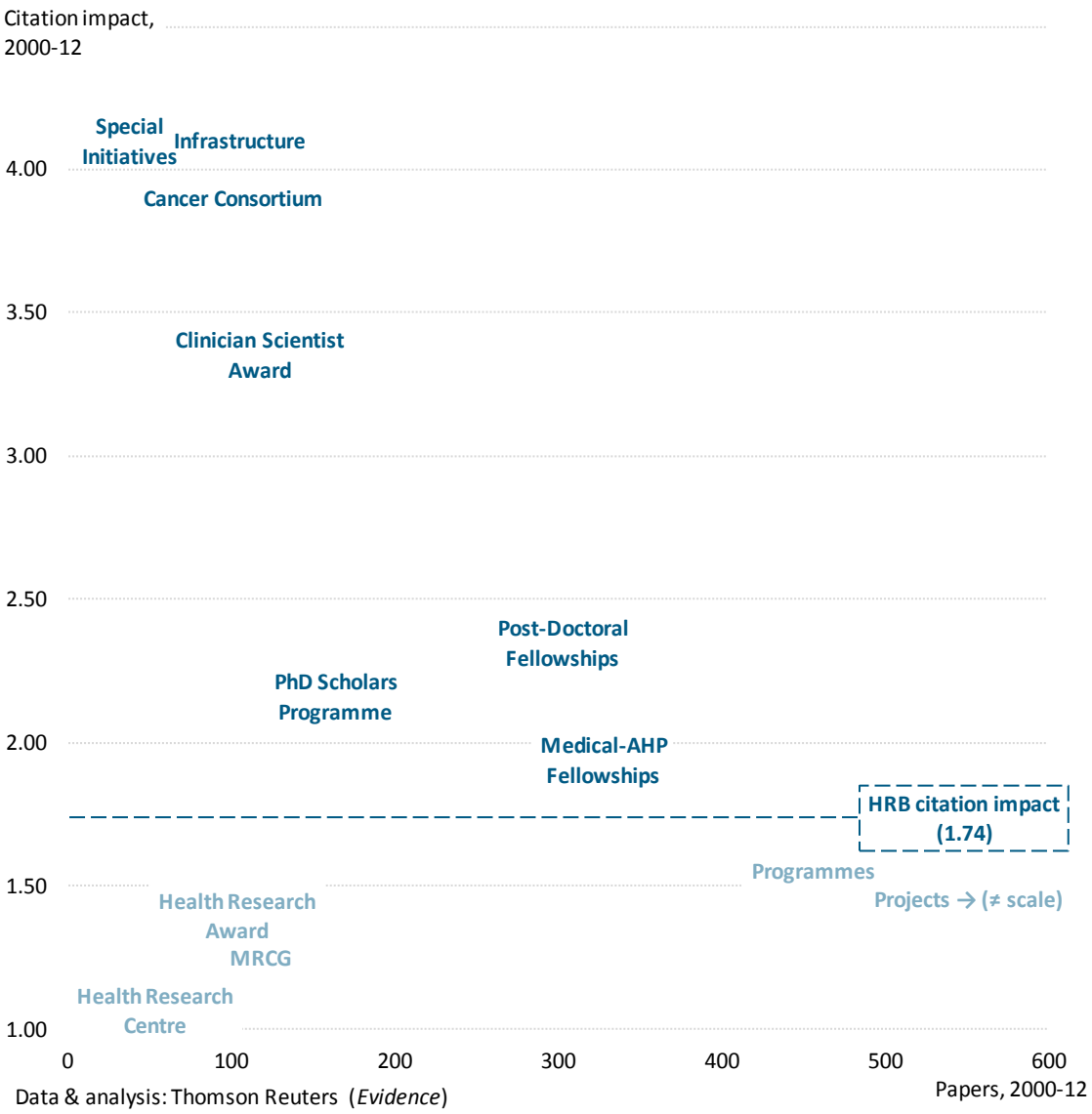


Table 5.2 HRB-supported papers and citation impact by HRB funding scheme, 2000–12

For some aggregated funding schemes (e.g. 'Projects') the sum of the aggregate is less than the sum of its parts. This is because a paper[6] may have dual classifications (e.g. 'Research Project Grant' and 'Global Health Research Award', but it is counted as a 'Project' only once. Projects where paper numbers are <20 are shown in grey.

HRB funding scheme and grant type	Papers	Citation impact
Cancer Consortium	**101**	**3.96**
Cancer Consortium awards	54	1.47
ICORG Cancer Clinical Trials Network	47	6.82
Clinician Scientist Award	**117**	**3.36**
Health Research Award	**103**	**1.40**
Health Research Centre	**53**	**1.07**
Infrastructure	**104**	**4.07**
Clinical Research Facility	45	4.72
Equipment	27	2.89
Health Information System	13	8.03
Imaging Award	19	1.52
Medical Research Charities Group Co-Funded Project	**118**	**1.25**
Medical-AHP Fellowships	**327**	**1.94**
Cochrane Training Fellowship	31	1.01
Health Professionals Fellowship	165	2.36
Medical Fellowship	124	1.69
Summer studentship	8	0.76
PhD Scholars Programme	**163**	**2.16**
Post-Doctoral Fellowships	**302**	**2.35**
Programmes	**455**	**1.56**
Programme Grant	284	1.73
Strategic Health Services R&D Award	46	1.04
Translational Research Programme	127	1.34
Projects	**1,661**	**1.46**
Global Health Research Award	22	1.58
Interdisciplinary Project	26	1.16
North-South cooperation grant	65	1.38
Partnership Award	32	0.79
Research Project Grant	1,528	1.48
Special Initiatives	**37**	**4.07**
Autism Genome Project	17	3.96
CHLAMYDIA	3	0.23
ELDERMET	16	5.17
JINGO	1	0.00

[6] For example, Bell, A (2011) Antimalarial Peptides: The Long and the Short of It. *Current Pharmaceutical Design*, 17: 2719-2731

6. Research performance by field

This section of the report analyses trends in papers and citation impact by the top 20 fields of HRB-supported papers (as measured by *Web of Science℠* journal category by volume). Data are provided in Table 6.1, and are visualised over time (Figure 6.2) and in a summary SWOT (strengths, weaknesses, opportunities and threats) analyses (Figure 6.3). Scope notes for these fields are provided in Annex 2.

Key findings

With the exception of two fields, citation impact is above the world average. These are also the only two fields that are notably below benchmarks for similar Irish clinical/health/pre-clinical and biological sciences research. Otherwise, HRB-supported papers perform very well across HRB's top 20 *Web of Science℠* journal categories. HRB-supported papers are particularly strong by volume and impact in Oncology, Immunology, Genetics & Heredity and Psychiatry.

Research strengths and opportunities

Citation impact is over twice the world average in the following fields:

- **Psychiatry** (2.61, 160 papers)
- **Clinical Neurology** (2.45, 127 papers)
- **Oncology** (2.32, 275 papers)
- **Immunology** (2.26, 225 papers)
- **Genetics & Heredity** (2.06, 165 papers)
- **General & Internal Medicine** (2.04, 110 papers)
- **Gastroenterology & Hepatology** (2.02, 90 papers)

Citation impact is over one and a half times greater than the world average in the following fields:

- **Biotechnology & Applied Microbiology** (1.69, 90 papers)
- **Pharmacology & Pharmacy** (1.64, 181 papers)

Citation impact is greater than (≥0.10) Irish benchmarks in the following fields:

- **Microbiology** (1.48, 180 papers)
- **Research & Experimental Medicine** (1.41, 106 papers)
- **Biophysics** (1.36, 72 papers)
- **Infectious Diseases** (1.29, 98 papers)
- **Haematology** (1.07, 90 papers)

Research threats and weaknesses

Citation impact is below the world average in the following fields:

- Cell Biology (0.84, 220 papers)
- Endocrinology & Metabolism (0.91, 85 papers)

Citation impact is not notably different (+/-0.10) from overall Irish research in the following fields:

- Peripheral Vascular Disease (1.32, 71 papers)
- Neurosciences (1.30, 273 papers)
- Biochemistry & Molecular Biology (1.17, 477 papers)
- Public, Environmental & Occupational Health (1.09, 84 papers)

Table 6.1 HRB-supported papers and citation impact by *Web of Science℠* journal category, 2000–12

Web of Science℠ journal category	Code	Papers			Citation impact		
		00-12	00-06	06-12	00-12	00-06	06-12
Biochemistry & Molecular Biology	BioChem	477	159	354	1.17	1.18	1.16
Oncology	Oncol	275	40	252	2.32	1.13	2.41
Neurosciences	NeuroSci	273	59	233	1.30	0.99	1.34
Immunology	Immun	225	70	172	2.26	2.33	2.21
Cell Biology	CellBio	220	62	178	0.84	0.91	0.82
Pharmacology & Pharmacy	Pharma	181	44	150	1.64	1.14	1.72
Microbiology	MicroBio	180	38	151	1.48	1.38	1.51
Genetics & Heredity	Genetics	165	36	142	2.06	1.17	2.24
Psychiatry	Psychiatry	160	32	137	2.61	1.64	2.71
Clinical Neurology	ClinNeuro	127	15	119	2.45	1.56	2.52
General & Internal Medicine	GenMed	110	12	104	2.04	0.78	2.12
Research & Experimental Medicine	ExpMed	106	24	89	1.41	2.09	1.20
Infectious Diseases	InfectDis	98	17	86	1.29	1.11	1.28
Biotechnology & Applied Microbiology	BioTech	90	22	75	1.69	1.25	1.75
Gastroenterology & Hepatology	Gastro	90	27	70	2.02	2.50	1.85
Haematology	Haema	90	25	73	1.07	1.36	0.94
Endocrinology & Metabolism	Endo	85	18	70	0.91	0.61	0.96
Public, Environmental & Occupational Health	PubHlth	84	3	82	1.09	3.01	1.02
Biophysics	BioPhys	72	24	58	1.36	1.26	1.35
Peripheral Vascular Disease	Vasc	71	16	59	1.32	1.19	1.34

Figure 6.1 Trends by *Web of Science*℠ journal category, 2000–06 and 2006–12

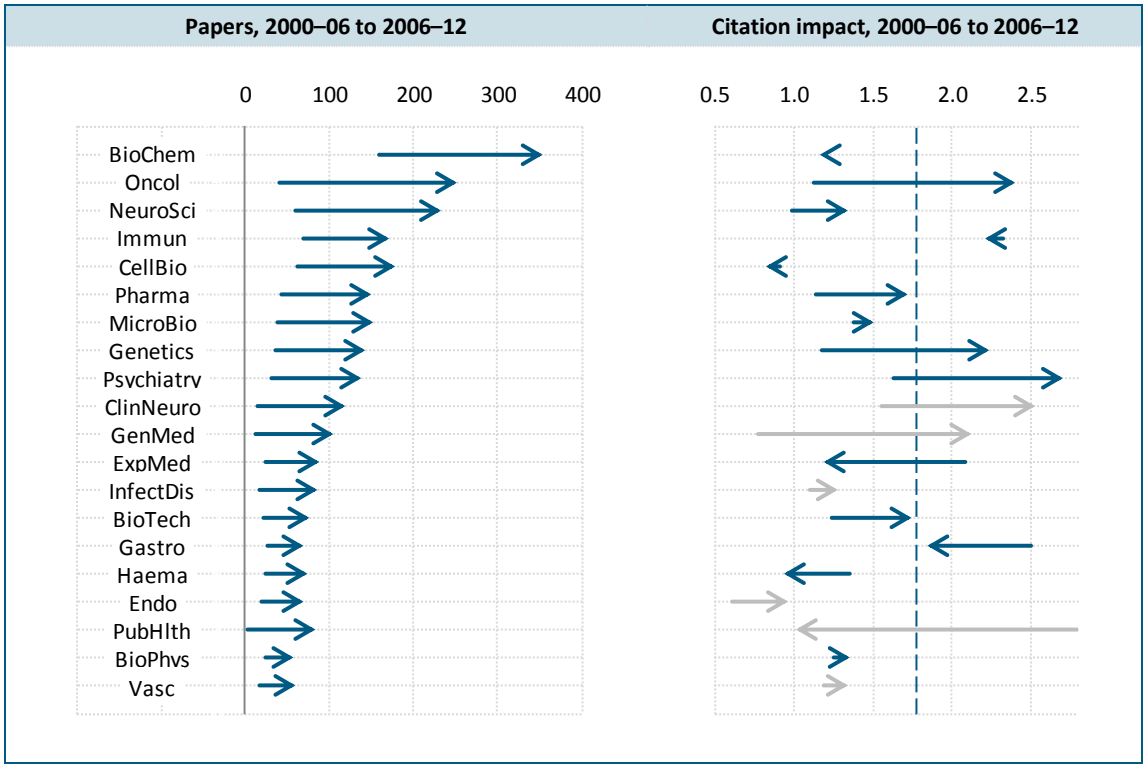
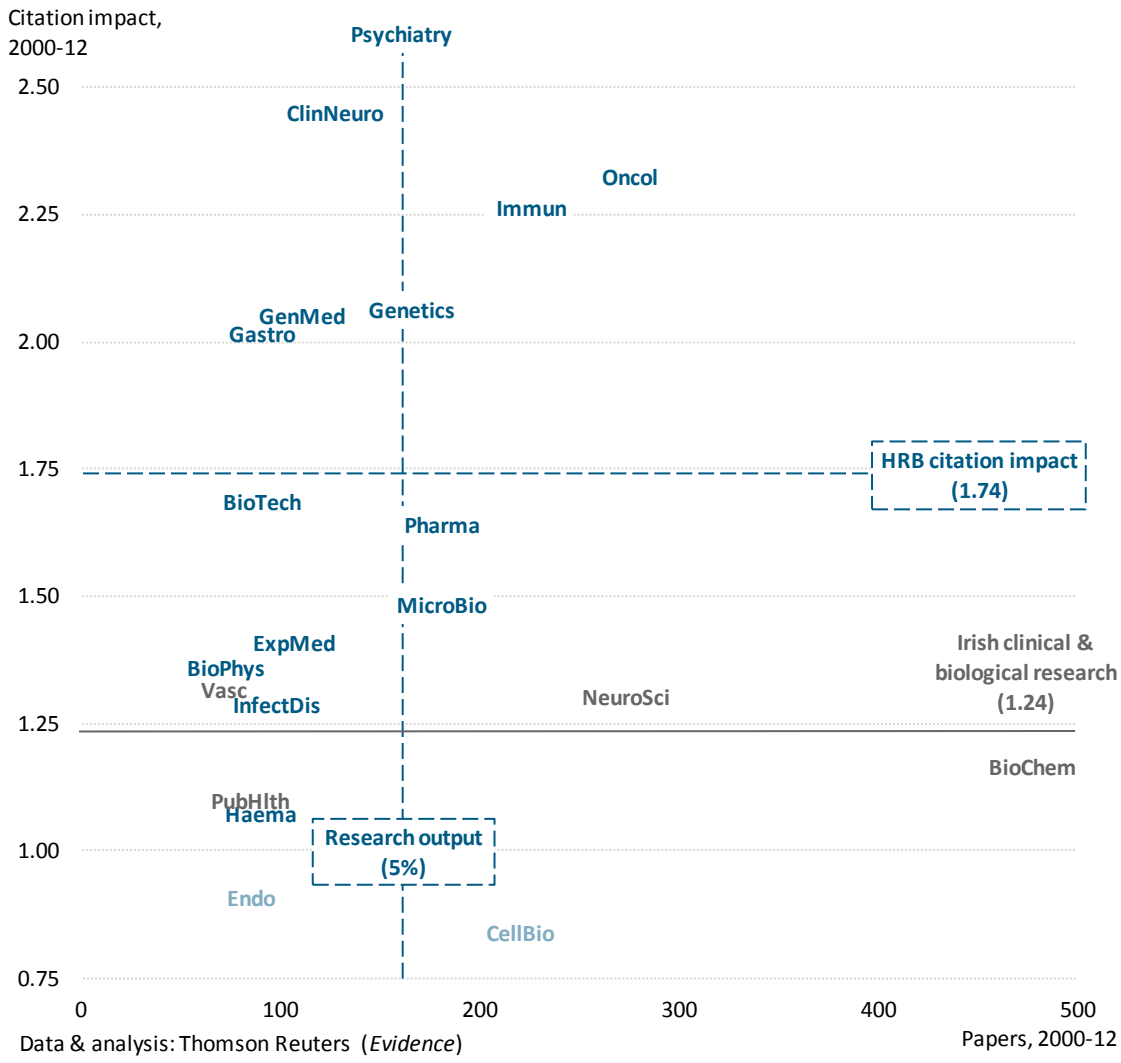


Figure 6.2 Strengths, weaknesses, opportunities and threats of HRB-supported papers, 2000–12

*Web of Science℠ journal categories are formatted relative to overall Irish research performance in that category, where if performance is ≥0.10 (**dark blue**), >-0.10 <0.10 (**grey**) and ≤-0.10 (**light blue**).*

Opportunities	**Strengths**
Web of Science℠ journal categories in the top left quadrant represent research opportunities. These are areas of higher citation impact relative to HRB-supported/Irish clinical/health/pre-clinical and biological sciences research, but with a lower share of HRB-supported papers (<5%).	*Web of Science℠* journal categories in the top right quadrant represent research strengths. These are areas of higher citation impact relative to HRB-supported/Irish clinical/health/pre-clinical and biological sciences research and with a higher share of HRB-supported papers (≥5%).



Data & analysis: Thomson Reuters (*Evidence*)

Web of Science℠ journal categories in the bottom left quadrant represent research weaknesses. These are areas of lower citation impact relative to HRB-supported/Irish clinical/health/pre-clinical and biological sciences research and with a lower share of HRB-supported papers (<5%).	*Web of Science℠* journal categories in the bottom right quadrant represent research threats. These are areas of lower citation impact relative to HRB-supported/Irish clinical/health/pre-clinical and biological sciences research, but with a higher share of HRB-supported papers (≥5%).
Weaknesses	**Threats**

7. Domestic and international research co-authorship

This section of the report analyses the co-authorship of HRB-supported papers, both domestic and international between 2000 and 2012. It also analyses the principal sectors of HRB-supported researchers and the principal countries engaged in internationally co-authored research.

Internationally co-authored research is a rapidly growing element of research activity.[7] The reasons for this have not been fully clarified but include increasing access to facilities and resources, increasing access to knowledge and increasing access to people and expertise. In addition, international co-authorship has been shown to be associated with an increase in the number of citations received by research papers, although this depend on the partner countries involved.[8] Co-authorship is likely to be a good indicator of collaboration, although there will be collaborations that do not result in co-authored papers, and there may also be co-authored papers that required limited collaboration. Alternative data-based approaches, for example using information about co-funding or international exchanges, have limitations in terms of both comprehensiveness and validity.

Key findings

- Two fifths of HRB-supported papers have been internationally co-authored (40.8%) and this has risen from around one-third of HRB-supported papers (33.8%, 2000-04) to over two-fifths (43.8%, 2008-12). Similarly, domestic co-authorship of HRB-supported papers has increased from 34.7% (2000-04) to 42.1% (2008-12). There is a citation impact gain with HRB-supported internationally co-authored papers. It is over twice the world average (2.28) and approaching two and a half times greater than the world average. HRB-supported domestically co-authored papers are similarly cited (1.66) to HRB-supported papers (1.74) overall.
- The citation impact of internationally co-authored papers in the HRB Clinical strategic pillar area is over three times the world average (3.29) compared to all papers in this strategic pillar area (2.20). In the HRB Biomedical strategic pillar area, internationally co-authored papers have a citation impact over twice the world average (2.11) compared to all papers in this strategic pillar area (1.67). The citation impact gain of internationally co-authored papers compared to all papers in the HRB Population Health and Health Services research strategic pillar area is more negligible (1.51 compared to 1.40, respectively). There is little difference in citation impact between the three HRB strategic pillar areas that were authored purely at the national level.
- 90% of HRB-supported papers have been produced in the academic sector in Ireland. The top five academic sector institutions in terms of number of HRB-supported papers include the major universities of Ireland: Trinity College Dublin, University College Dublin, the Royal College of Surgeons in Ireland, University College Cork and the National University of Ireland, Galway.

[7] Adams J and Wilsdo J (2006). The new geography of science: UK research and international collaboration (pp. 1-14). Leeds, UK: Evidence Ltd. Retrieved 27 February 2013 from http://www.demos.co.uk/files/Demos_Evidence_China.pdf

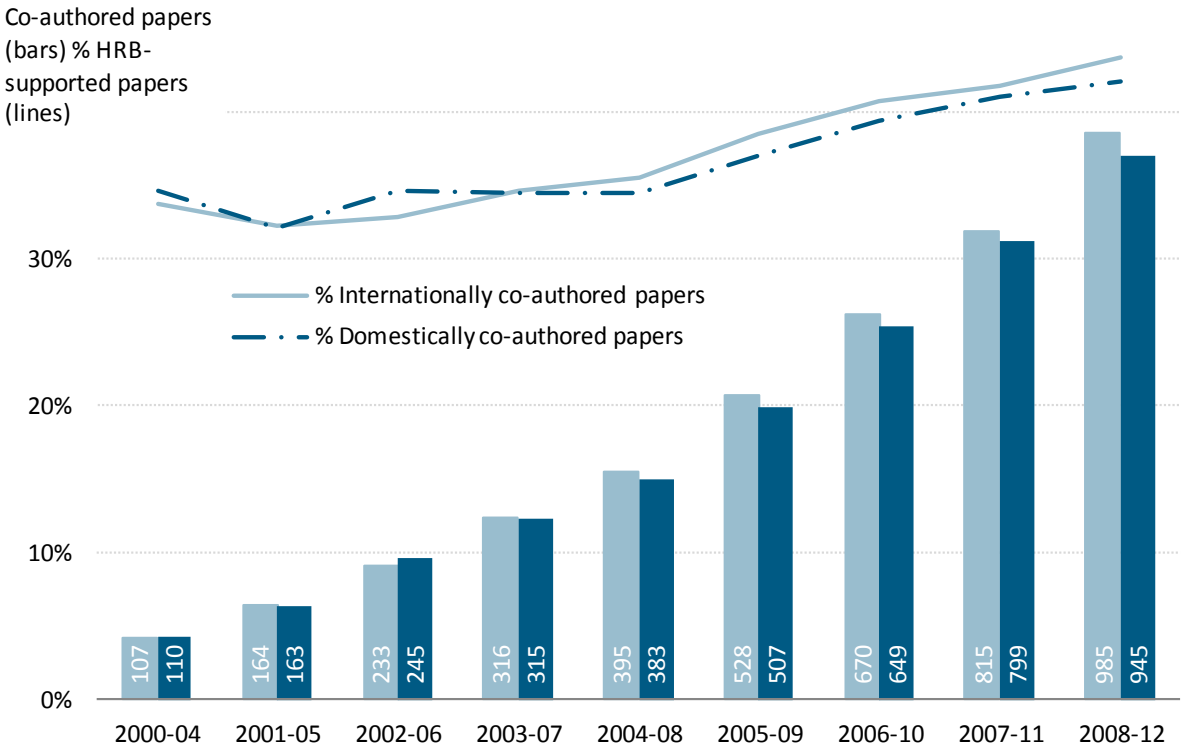
[8] Adams J, Gurney K and Marshall S (2007). Patterns of international collaboration for the UK and leading partners. London, UK: UK Office of Science and Innovation. Retrieved 27 February 2013 from http://www.berr.gov.uk/files/file40396.pdf

- 33.8% of HRB-supported papers have been produced in the health sector in Ireland. The top five health sector institutions in terms of number of HRB-supported papers include the major university hospitals of Ireland: St James's Hospital, St Vincent's University Hospital, Beaumont Hospital, Mater Misericordiae University Hospital and Cork University Hospital.
- The principal countries engaged in co-authored papers with HRB-supported researchers include the USA and the UK, both of which account for over two-fifths of internationally co-authored HRB-supported papers (43.6% and 43.1%, respectively). There has been a strong Anglophone as well as European dimension to HRB-supported internationally co-authored papers.

7.1 Trends in co-authorship

Overall, two-fifths (40.8%) of HRB-supported papers have an international co-author (internationally co-authored papers). Similarly, two-fifths (40.0%) of HRB-supported papers have two or more institutional co-authors (domestically co-authored papers).[9] Both internationally and domestically co-authored papers have increased as a percentage of HRB-supported papers (Figure 7.1). The trends have been similar; international co-authorship has risen from 33.8% (2000–04) to 43.8% (2008–12) of HRB-supported papers and domestic co-authorship has risen from 34.7% (2000–04) to 42.1% (2008–12) of HRB-supported papers.

Figure 7.1 Internationally and domestically co-authored papers, 2000–12



Data & analysis: Thomson Reuters (*Evidence*)

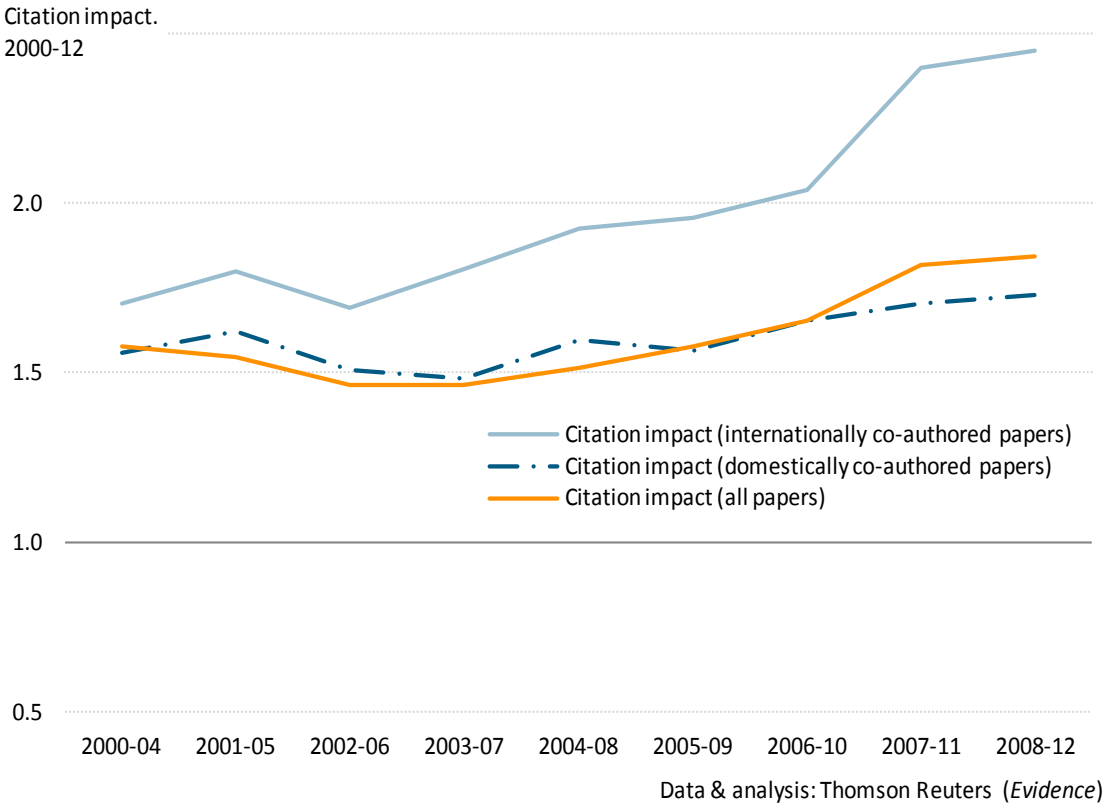
[9] See 'Assigning papers to addresses' in Annex 1.

7.2 Citation impact gain of research co-authorship

Internationally co-authored research is associated with a citation impact gain. The citation impact of HRB-supported papers overall is 1.74; however, for internationally co-authored papers, it is over twice the world average (2.28) and has risen from 1.70 (2000–04) to 2.45 (2008–12), as shown in Figure 7.2.

This is higher than the citation impact of domestically co-authored papers (1.66), which has risen from 1.56 (2000–04) to 1.73 (2008–12). This parallels, but is similar to, the trend in citation impact for overall HRB-supported papers.

Figure 7.2 Citation impact of internationally and domestically co-authored papers, 2000–12

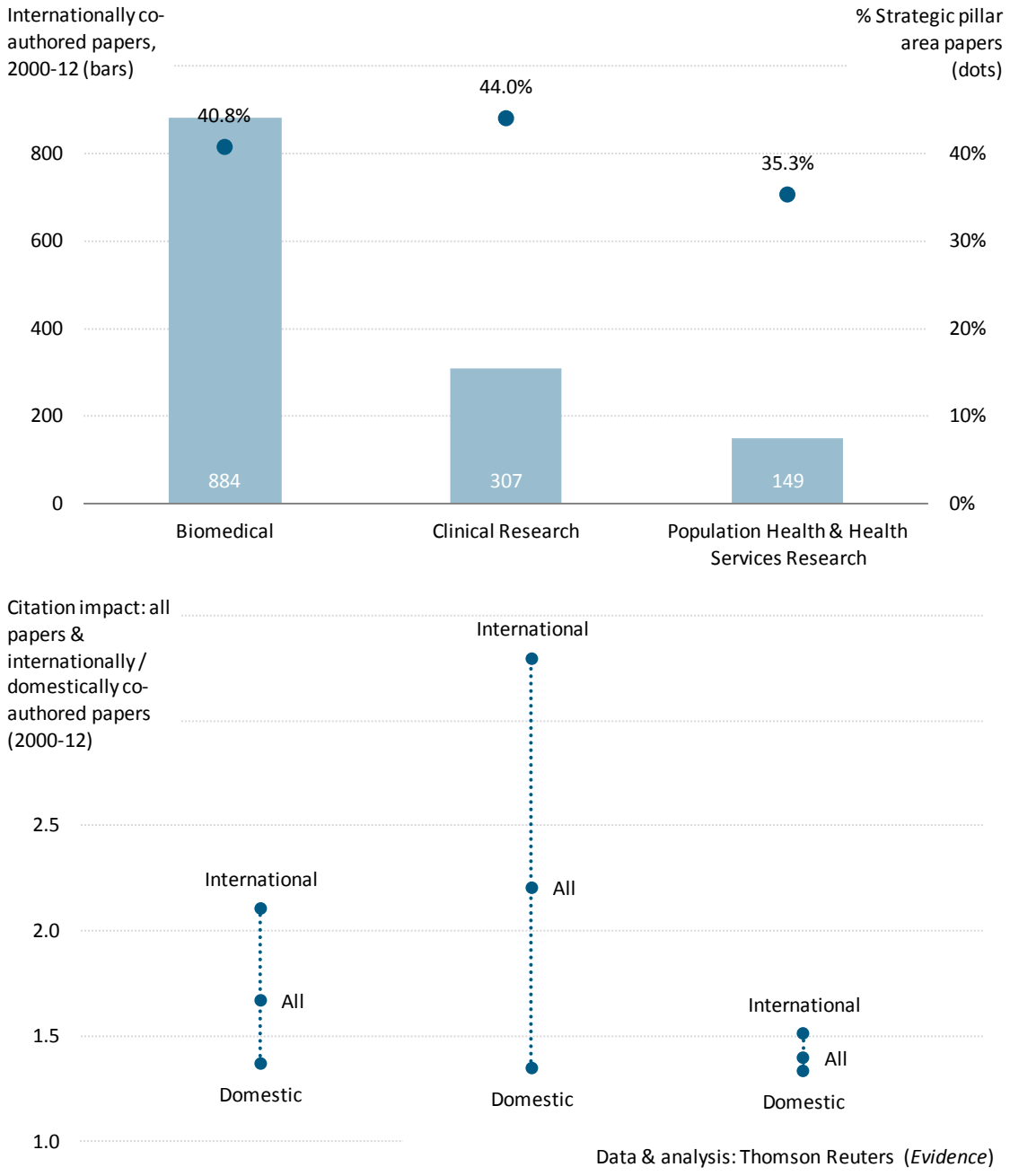


7.3 Internationally co-authored papers by HRB strategic pillar area

Figure 7.3 shows that the Biomedical strategic pillar area accounts for 884 internationally co-authored papers accounting for around two-fifths of research output in this strategic pillar area. This compares to 44.0% of HRB-supported papers in the Clinical research strategic pillar area and 35.3% of Population Health and Health Services research. The citation impact gain of HRB-supported internationally co-authored papers is over twice the world average in the Biomedical strategic pillar area (2.11 compared to 1.67 for all research), but over three times the world average in the Clinical

research strategic pillar area (3.29 compared to 2.20 for all research). The citation impact gain of HRB-supported internationally co-authored papers in Population Health and Health Services research (1.51 compared to 1.40 for all research) is negligible. Domestically authored research has a very similar citation impact across the three strategic pillar areas: Biomedical (1.37), Clinical (1.35) and Population Health and Health Services research (1.33). This suggests that internationally co-authored research is driving the higher citation impact of the HRB Biomedical and Clinical strategic pillar areas.

Figure 7.3 **HRB-supported internationally co-authored papers by HRB strategic pillar area, as a percentage of research output and the citation impact of all HRB-supported papers, and internationally and domestically co-authored papers, 2000–12**

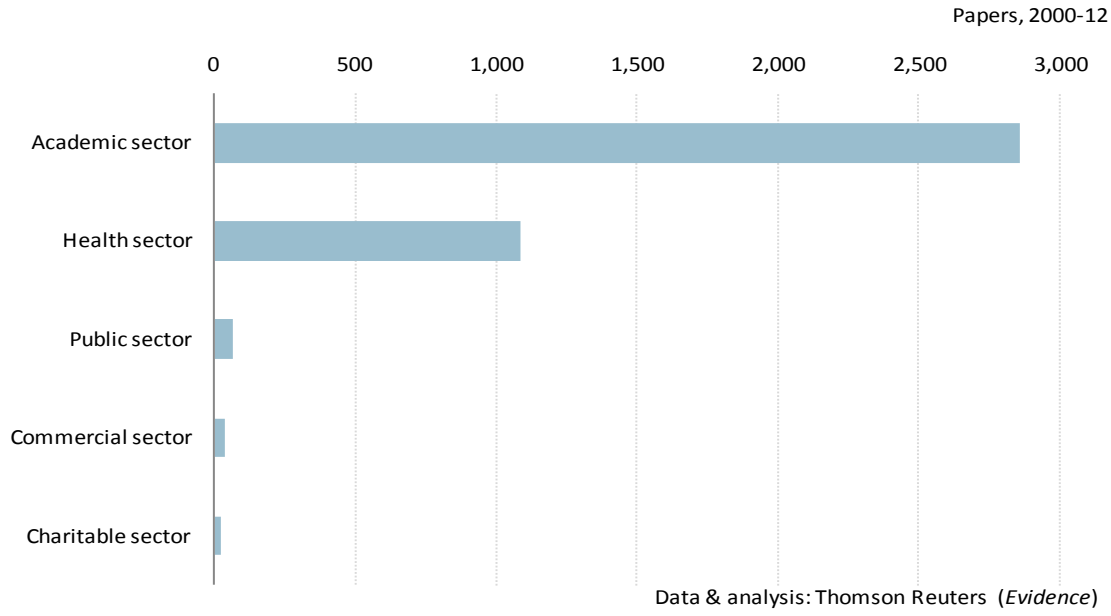


7.4 Sectoral breakdown of HRB-supported papers

Figure 7.4.1 shows the sectoral breakdown of HRB-supported papers between 2000 and 2012. The following definitions are used:

- academic sector: universities and university sector institutions
- health sector: used for hospital-based research and research undertaken in primary health care
- public sector: addresses associated with non-health-related governmental bodies
- commercial sector: referring to an address which can be associated with a company defined as a sole trader, public limited company or limited company
- charitable sector: referring to smaller charities, but most charitable medical research will be associated with the academic and health sector, and these classifications take precedence.

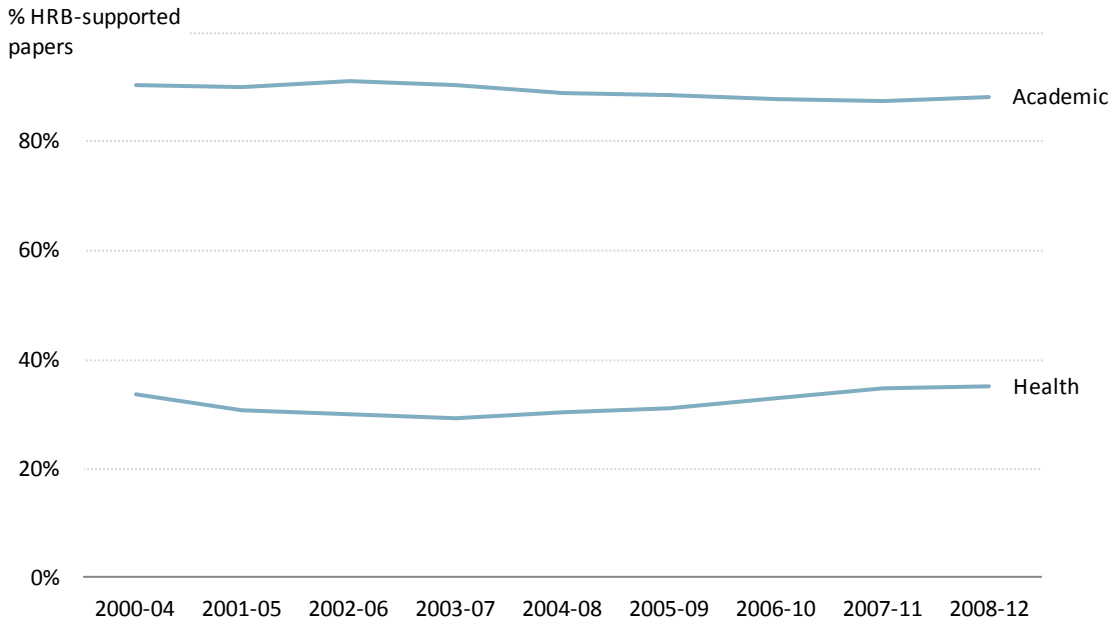
Figure 7.4.1 HRB-supported papers by principal sector, 2000–12



The academic sector has produced nearly 90% of HRB-supported papers (2,862 papers, 88.7% of HRB-supported papers). The top five academic sector institutions in terms of number of HRB-supported papers include the major universities of Ireland: Trinity College Dublin, University College Dublin, the Royal College of Surgeons in Ireland, University College Cork and the National University of Ireland, Galway. The health sector has produced around one-third of HRB-supported papers (1,090 papers, 33.8% of HRB-supported papers). The top five health sector institutions in terms of number of HRB-supported papers include the major university hospitals of Ireland: St James's Hospital, St Vincent's University Hospital, Beaumont Hospital, Mater Misericordiae University Hospital and Cork University Hospital.

These proportions are more or less constant over time, with the academic sector accounting for 90.5% of HRB-supported papers (2000–04) dropping only slightly to 88.3% (2008–12) although the direction of the trend is somewhat downwards. The health sector accounted for 33.4% of HRB-supported papers (2000–04) rising only slightly to 35.2% (2008–12) although the direction of the trend is somewhat upwards.

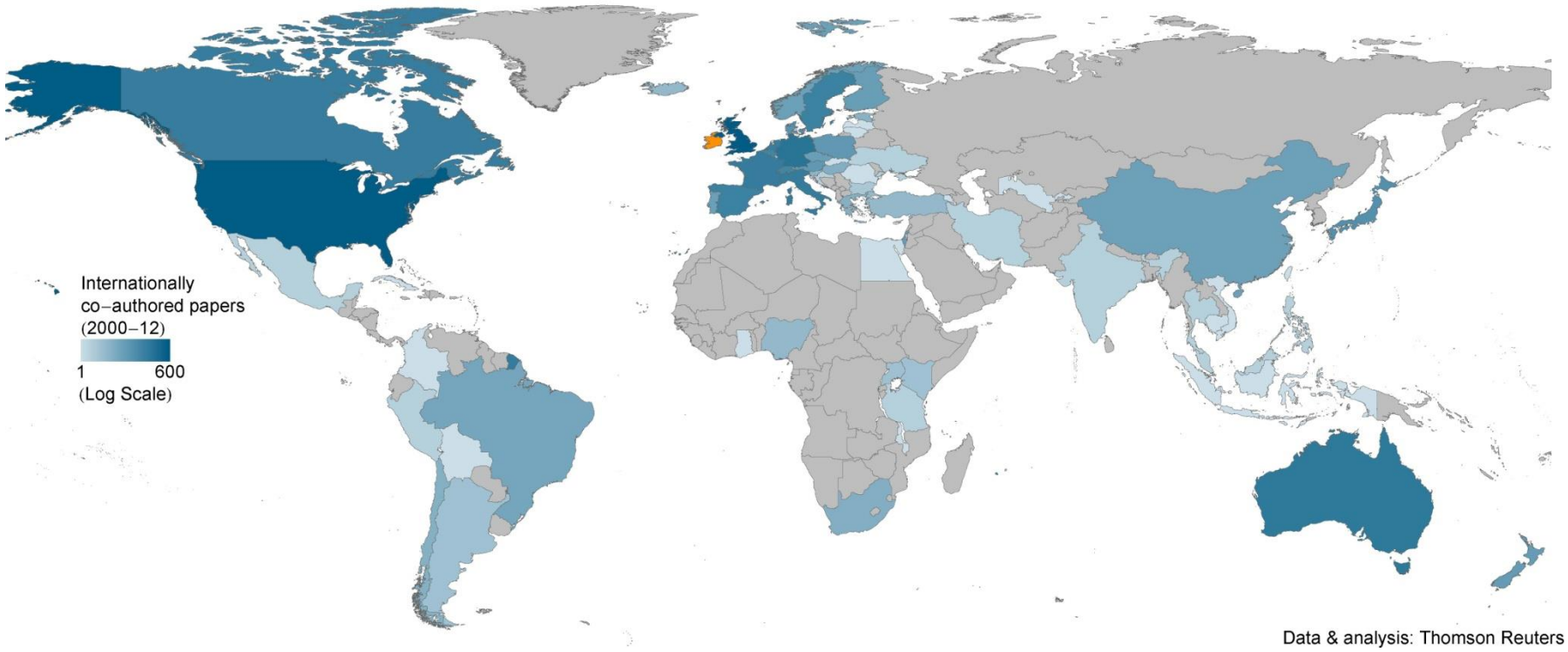
Figure 7.4.2 HRB-supported papers (academic and health sectors) over time



Data & analysis: Thomson Reuters (*Evidence*)

7.5 Map of HRB-supported internationally co-authored papers

The principal countries engaged in internationally co-authored papers with HRB-supported researchers include (with internationally co-authored papers, and as a percentage of internationally co-authored papers): USA (574, 43.6%), UK (567, 43.1%), Germany (166, 12.6%), Australia (136, 10.3%), Italy (115, 8.7%), France (114, 8.7%), Canada (107, 8.1%) and Netherlands (101, 7.7%). There is, consequently, a strong Anglophone as well as European dimension to HRB-supported internationally co-authored papers.



Annex 1: Bibliometrics and citation analyses

Bibliometrics is about publications and their citations. The academic field emerged from 'information science' and now usually refers to the methods used to study and index texts and information.

Publications cite other publications. These citation links grow into networks, and their numbers are likely to be related to the significance or impact of the publication. The meaning of the publication is determined from keywords and content. Citation analysis and content analysis have therefore become a common part of bibliometric methodology. Historically, bibliometric methods were used to trace relationships amongst academic journal citations. Now, bibliometrics are important in indexing research performance.

Bibliometric data have particular characteristics of which the user should be aware, and these are considered here.

Journal papers (publications, sources) report research work. Papers refer to or 'cite' earlier work relevant to the material being reported. New papers are cited in their turn. Papers that accumulate more citations are thought of as having greater 'impact', which is interpreted as significance or influence on their field. Citation counts are therefore recognised as a measure of impact, which can be used to index the excellence of the research from a particular group, institution or country.

The origins of citation analysis as a tool that could be applied to research performance can be traced to the mid-1950s, when Eugene Garfield proposed the concept of citation indexing and introduced the Science Citation Index, the Social Sciences Citation Index and the Arts and Humanities Citation Index, produced by the Institute of Scientific Information (currently the IP & Science business of Thomson Reuters).[10]

We can count citations, but they are only 'indicators' of impact or quality – not metrics. Most impact indicators use average citation counts from groups of papers, because some individual papers may have unusual or misleading citation profiles. These outliers are diluted in larger samples.

Data source

The data we use come from the Thomson Reuters databases underlying the *Web of Knowledge℠*, which gives access not only to journals but also to conference proceedings, books, patents, websites, and chemical structures, compounds and reactions. It has a unified structure that integrates all data and search terms and therefore provides a level of comparability not found in other databases. It is widely acknowledged to be the world's leading source of citation and bibliometric data. The *Web of Science℠* is one part of the *Web of Knowledge℠*, and focuses on research published in journals, conferences and books in science, medicine, arts, humanities and social sciences.

The *Web of Science℠* was created as an awareness and information retrieval tool but it has acquired an important secondary use as a tool for research evaluation, using citation analysis and bibliometrics. Data coverage is both current and retrospective in the sciences, social sciences, arts and humanities, in some cases dating back to 1900. Within the research community this data source is often still referred to by the acronym 'ISI'.

[10] Garfield, E (1955) Citation Indexes for Science – New dimension in documentation through association of ideas. *Science*: **122**, 108-111.

Unlike other databases, the *Web of Science℠* and underlying databases are selective i.e. the journals abstracted are selected using rigorous editorial and quality criteria. The authoritative, multidisciplinary content covers over 12,000 of the highest-impact journals worldwide, including Open Access journals, and over 150,000 conference proceedings. The abstracted journals encompass the majority of significant, frequently cited scientific reports and, more importantly, an even greater proportion of the scientific research output that is cited. This selective process ensures that the citation counts remain relatively stable in given research fields and do not fluctuate unduly from year to year, which increases the usability of such data for performance evaluation.

Evidence, now as part of Thomson Reuters, has extensive experience with databases on research inputs, activity and outputs, and it has developed innovative analytical approaches for benchmarking and interpreting international, national and institutional research impact.

Database categories

The source data can be grouped in various classification systems. Most of these are based on groups of journals that have a relatively high cross-citation linkage and naturally cluster together. Custom classifications use subject maps in third-party data such as the OECD categories set out in the Frascati manual.

Thomson Reuters frequently uses the broader field categories in the *Essential Science Indicators* system and the finer journal categories in the *Web of Science℠*. There are 22 fields in *Essential Science Indicators* and 254 fields in *Web of Science℠*. In either case, our bibliometric analyses draw on the full range of data available in the underlying database, so analyses in our reports will differ slightly from anything created 'on the fly' from data in the web interface.

The lists of journal categories in these systems are set out at the end of this report.

Most analyses start with an overall view across the data, then move to a view across broad categories and only then focus in at a finer level in the areas of greatest interest to policy, programme or organisational purpose.

Assigning papers to addresses

A paper is assigned to each country and each organisation whose address appears at least once in relation to any author of that paper. One paper counts once and only once for each assignment; however there may be many address variants occur for the country or organisation. No weighting is applied.

For example, a paper has five authors, thus:

Author	Organisation	Country		
Gurney, KA	Uni Leeds	UK	**Counts for Uni Leeds**	**Counts for UK**
Adams, J	Uni Leeds	UK	No gain for Univ Leeds	No gain for UK
Kochalko, D	Uni C San Diego	USA	**Counts for UCSD**	**Counts for USA**
Munshi, S	Gujarat Uni	India	**Counts for Gujarat Uni**	**Counts for India**
Pendlebury, D	Uni Oregon	USA	**Counts for Uni Oregon**	No gain for USA

So, this one paper with five authors would be included once in the tallies for each of four universities and once in the tallies for each of three countries.

Work carried out within Thomson Reuters, and research published elsewhere, indicates that fractional weighting based on the balance of authors by organisation and country makes little difference to the conclusions of an analysis at an aggregate level. Such fractional analysis can introduce unforeseen errors in the attempt to create a detailed but uncertain assignment. Partitioning credit would make a greater difference at a detailed, group level but the analysis can then be manually validated.

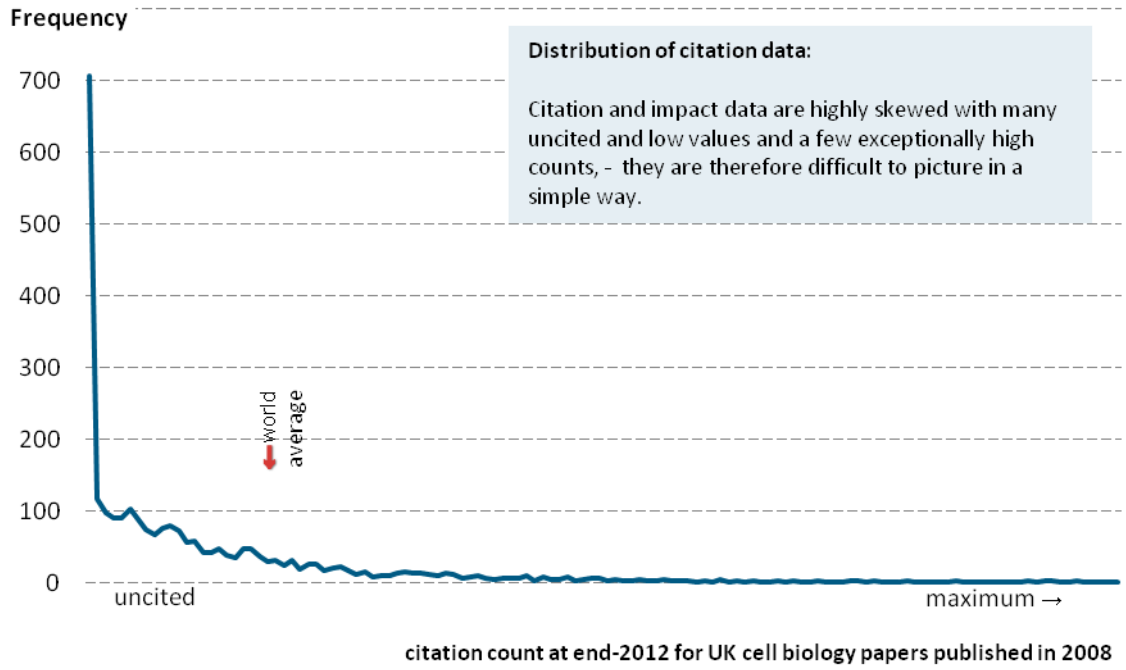
Citation counts

A publication accumulates citation counts when it is referred to by more recent publications. Some papers get cited frequently and many get cited rarely or never, so the distribution of citations is highly skewed.

Why are many papers never cited? Certainly, some papers remain uncited because their content is of little or no impact, but that is not the only reason. It might be because they have been published in a journal not read by researchers to whom the paper might be interesting. It might be that they represent important but 'negative' work reporting a blind alley to be avoided by others. The publication may be a commentary in an editorial, rather than a normal journal article, and thus of general rather than research interest. Or it might be that the work is a 'sleeping beauty' that has yet to be recognised for its significance.

Other papers can be very highly cited: hundreds, even thousands of times. Again, there are multiple reasons for this. Most frequently cited work is being recognised for its innovative significance and impact on the research field of which it speaks. Impact here is a good reflection of quality: it is an indicator of excellence. But there are other papers which are frequently cited because their significance is slightly different: they describe key methodology; they are a thoughtful and wide-ranging review of a field; or they represent contentious views which others seek to refute.

Citation analysis cannot make value judgements about why an article is uncited nor about why it is highly cited. The analysis can only report the citation impact that the publication has achieved. We normally assume, based on many other studies linking bibliometric and peer judgements, that high citation counts correlate on average with the quality of the research.



The figure shows the skewed distribution of more or less frequently cited papers from a sample of UK-authored publications in cell biology. The skew in the distribution varies from field to field. It is designed to compensate for issues such as the fact that actual citation counts must be normalised, or rebased, against a world baseline.

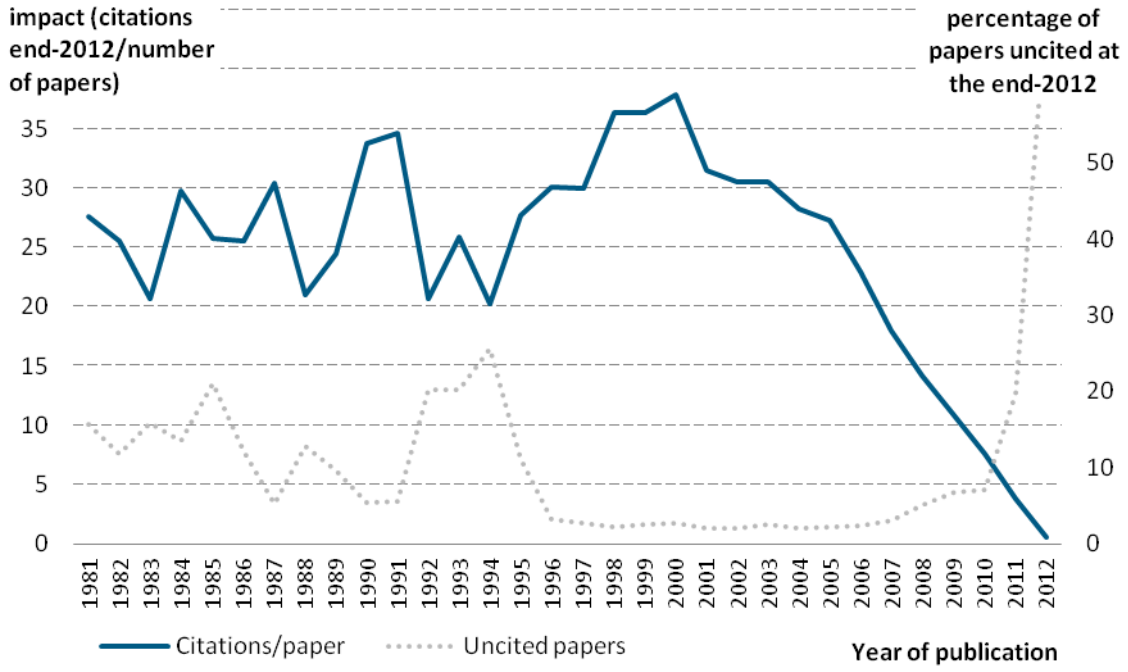
We do not seek to account separately for the effect of self-citation. If the citation count is significantly affected by self-citation, then the paper is likely to have been infrequently cited. This is therefore only of consequence for low-impact activity. Studies show that for large samples at national and organisational level, the effect of self-citation has little or no effect on the analytical outcomes and would not alter interpretation of the results.

Time factors

Citations accumulate over time. Older papers therefore have, on average, more citations than more recent work. The graph below shows the pattern of citation accumulation for a set of 33 journals in the journal category ***Materials Science, Biomaterials***. Papers less than eight years old are, on average, still accumulate additional citations. The citation count goes on to reach a plateau for older sources.

The graph shows that the percentage of papers that have never been cited drops over about five years. Beyond five years, between 5% and 10% or more of papers remain uncited.

Account must be taken of these time factors in comparing current research with historical patterns. For these reasons, it is sometimes more appropriate to use a fixed five-year window of papers and citations to compare two periods than to look at the longer term profile of citations and of uncitedness for a recent year and an historical year.



Discipline factors

Citation rates vary between disciplines and fields. For the UK science base as a whole, a ten year period produces a general plateau beyond which few additional citations would be expected. On the whole, citations accumulate more rapidly and plateau at a higher level in biological sciences than in physical sciences, and natural sciences generally cite at a higher rate than social sciences.

Papers are assigned to disciplines (journal categories or research fields) by Thomson Reuters, bringing cognate research areas together. The journal category classification scheme has been recently revised and updated. Before 2007, journals were assigned to the older, well-established Current Contents categories, which were informed by extensive work by Thomson and the research community since the early 1960s. This scheme has been superseded by the 252 *Web of Science℠* journal categories, which allow for greater disaggregation for the growing volume of research which is published and abstracted.

Papers are allocated according to the journal in which the paper is published. Some journals may be considered to be part of the publication record for more than one research field. As the example below illustrates, the journal *Acta Biomaterialia* is assigned to two journal categories: **Materials Science**, **Biomaterials and Engineering**, **Biomedical**.

Very few papers are not assigned to any research field and, as such, will not be included in specific analyses using normalised citation impact data. The journals included in the Thomson Reuters databases, and how they are selected, are detailed here http://scientific.thomsonreuters.com/mjl/.

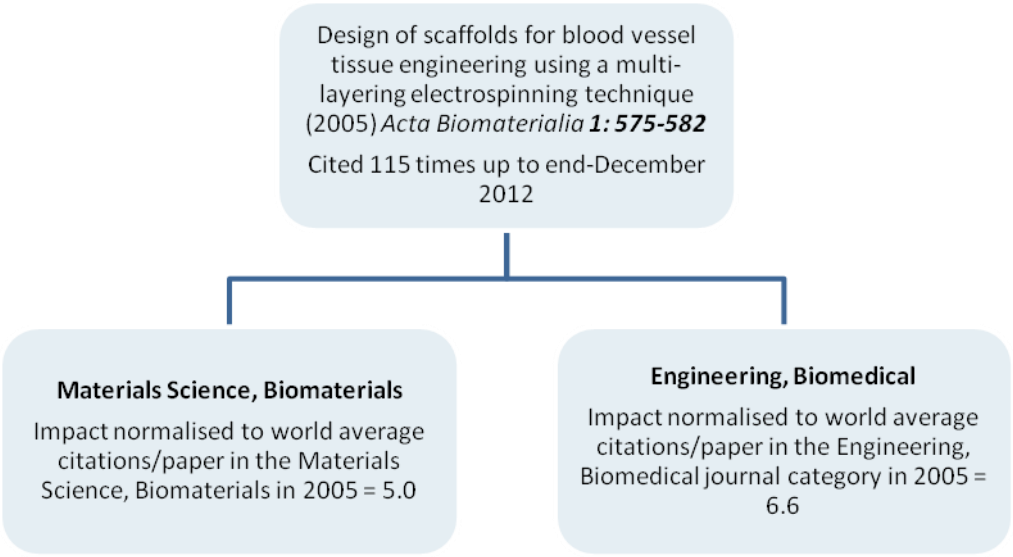
Some journals with a very diverse content, including the prestigious journals *Nature* and *Science* were classified as **Multidisciplinary** in databases created prior to 2007. The papers from these **Multidisciplinary** journals are now re-assigned to more specific research fields using an algorithm based on the research area(s) of the references cited by the article.

Normalised citation impact

Because citations accumulate over time at a rate that is dependent upon the field of research, all analyses must take both field and year into account. In other words, because the absolute citation count for a specific article is influenced by its field and by the year it was published, we can only make comparisons of indexed data after normalising with reference to these two variables.

We only use citation counts for reviews and articles in calculations of impact, because document type influences the citation count. For example, a review will often be cited more frequently than an article in the same field, but editorials and meeting abstracts are rarely cited and citation rates for conference proceedings are extremely variable. The most common normalisation factors are the average citations per paper for (1) the year and (2) either the field or the journal in which the paper was published. This normalisation is also referred to as 'rebasing' the citation count.

Impact is therefore most commonly analysed in terms of 'normalised impact', or NCI. The following schematic illustrates how the normalised citation impact is calculated at paper level and at journal category level.



This article in the journal *Acta Biomaterialia* is assigned to two journal categories: **Materials Science, Biomaterials** and **Engineering, Biomedical**. The world average baselines for, as an example, **Materials science, Biomaterials** are calculated by summing the citations to all the articles and reviews published worldwide in the journal *Acta Biomaterialia* and the other 32 journals assigned to this category for each year, and dividing this by the total number of articles and reviews published in the journal category. This gives the category-specific normalised citation impact (in the above example the category-specific NCI_F for **Materials Science, Biomaterials** is 5.0 and the category-specific NCI_F for **Engineering, Biomedical** is higher at 6.6). Most papers (nearly two-thirds) are assigned to a single journal category whilst a minority are assigned to more than 5.

Citation data provided by Thomson Reuters are assigned on an annual census date referred to as the Article Time Period. For the majority of publications, the Article Time Period is the same as the year of publication, but for a few publications (especially those published at the end of the calendar

year in less mainstream journals) the Article Time Period may vary from the actual year of publication.

World average impact data are sourced from the Thomson Reuters National Science Indicators baseline data for 2012.

Mean normalised citation impact

Research performance has historically been indexed by using average citation impact, usually compared to a world average that accounts for time and discipline. As noted, however, the distribution of citations among papers is highly skewed because many papers are never cited, while a few papers accumulate very large citation counts. That means that an average may be misleading if assumptions are made about the distribution of the underlying data.

In fact, almost all research activity metrics are skewed: for research income, PhD numbers and publications, there are many low-activity values and a few exceptionally high values. In reality, therefore, the skewed distribution means that average impact tends to be greater than, and often significantly different from, either the median or mode in the distribution. This should be borne in mind when reviewing analytical outcomes.

The average (normalised) citation impact can be calculated at an individual paper level where it can be associated with more than one journal category. It can also be calculated for a set of papers at any level from a single country to an individual researcher's output. In the example above, the average citation impact of the *Acta Biomaterialia* paper can be expressed as ((5.0 + 6.6)/2) = 5.8.

Impact Profiles®

Thomson Reuters has developed a bibliometric methodology[11] which shows the proportion of papers that are uncited and the proportion that lie in each of eight categories of relative citation rates, normalised (rebased) to world average. An Impact Profile® enables an examination and analysis of the strengths and weaknesses of published outputs relative to world average and relative to a reference profile. This provides much more information about the basis and structure of research performance than conventionally reported averages in citation indices.

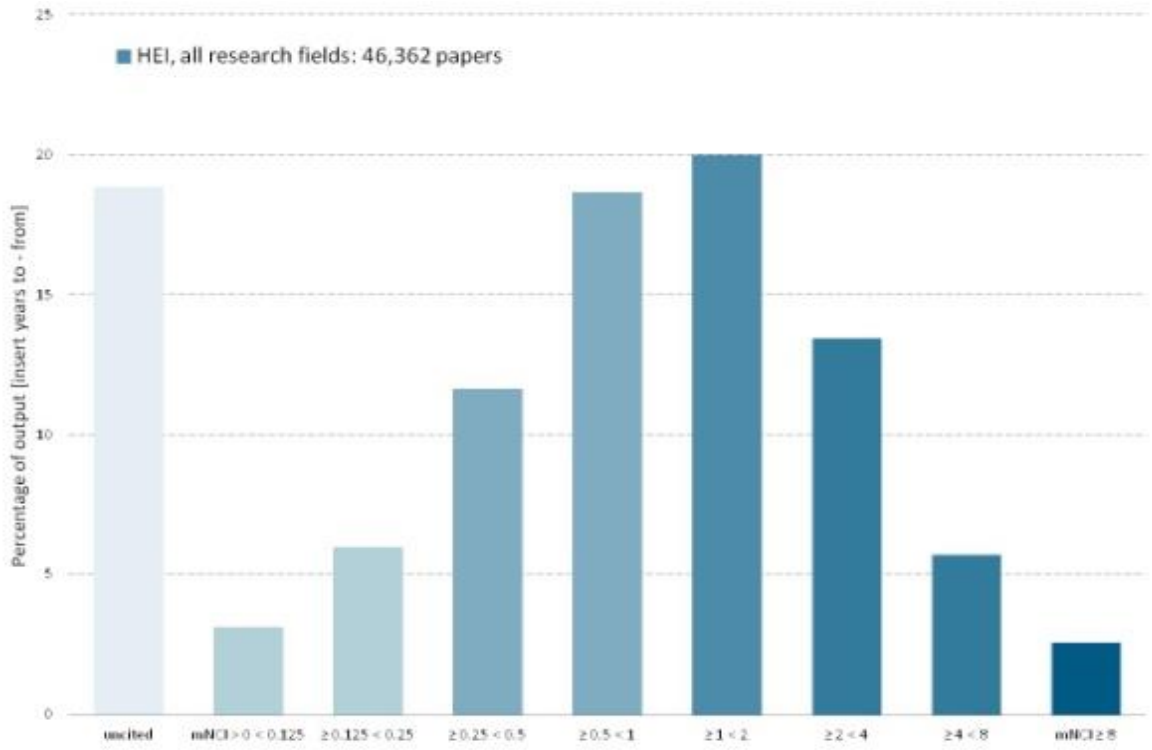
Papers which are "highly cited" are often defined in Thompson Reuters reports as those with an average citation impact (NCI_F) greater than or equal to 4.0 i.e. those papers which have received greater than, or equal to, four times the world average number of citations for papers in that subject published in that year. This differs from the Thomson Reuters database of global highly cited papers, which are the top 1% most frequently cited for their field and year. The top percentile is a powerful indicator of leading performance but it is too stringent a threshold for most management analyses.

The proportion of uncited papers in a dataset can be compared to the benchmark for the UK, the USA or any other country. Overall, in a typical ten-year sample, around one-quarter of papers have not been cited within the 10-year period; the majority of these are, of course, those that are most recently published.

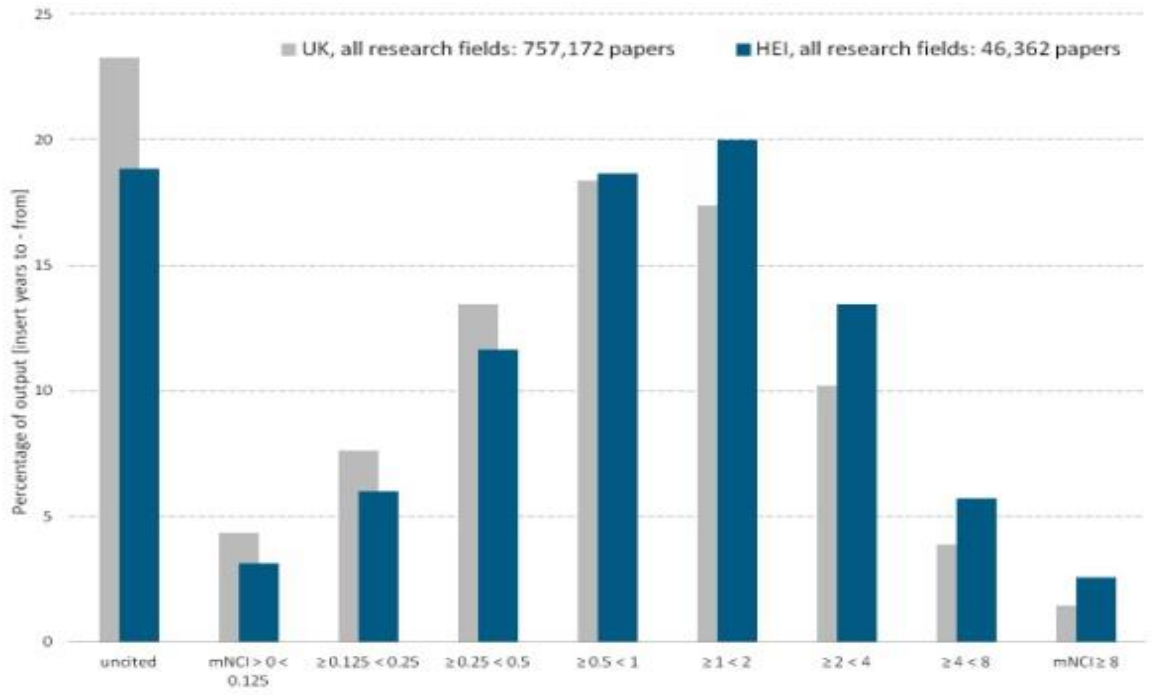
[11] Adams J, Gurney K and Marshall S (2007) Profiling citation impact: A new methodology. *Scientometrics* **72**: 325-344.

The Impact Profile® histogram can be presented in a number of ways, which are illustrated below.

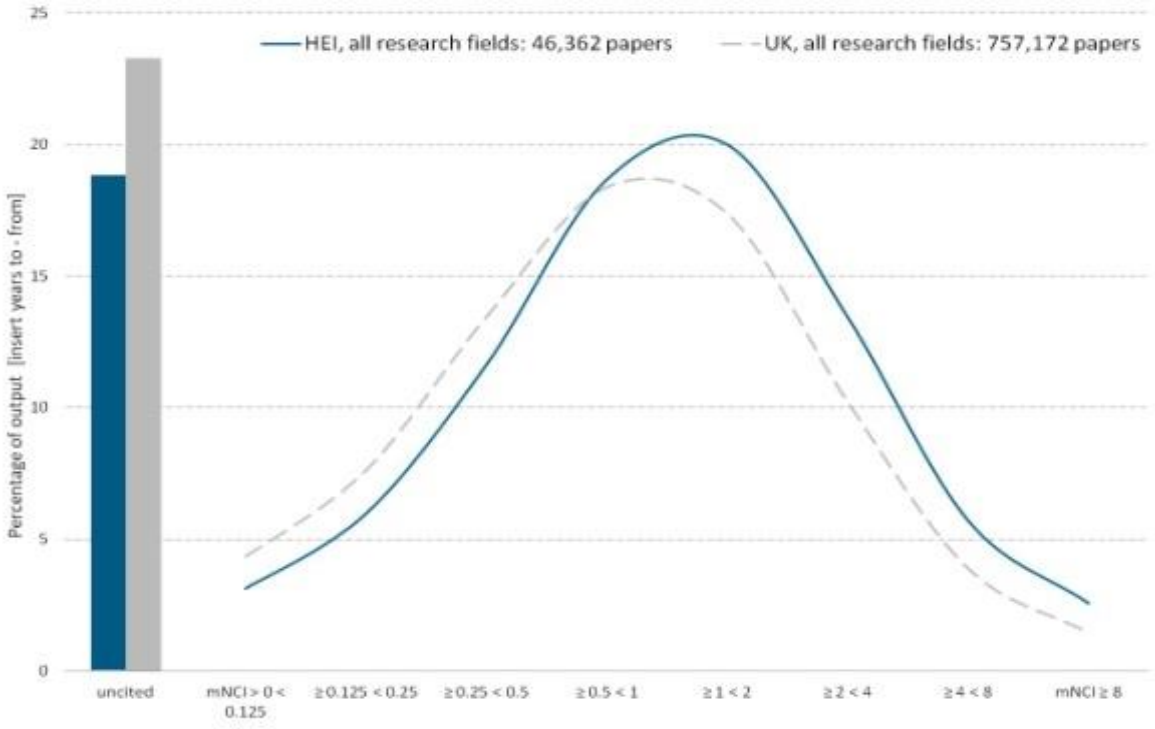
A



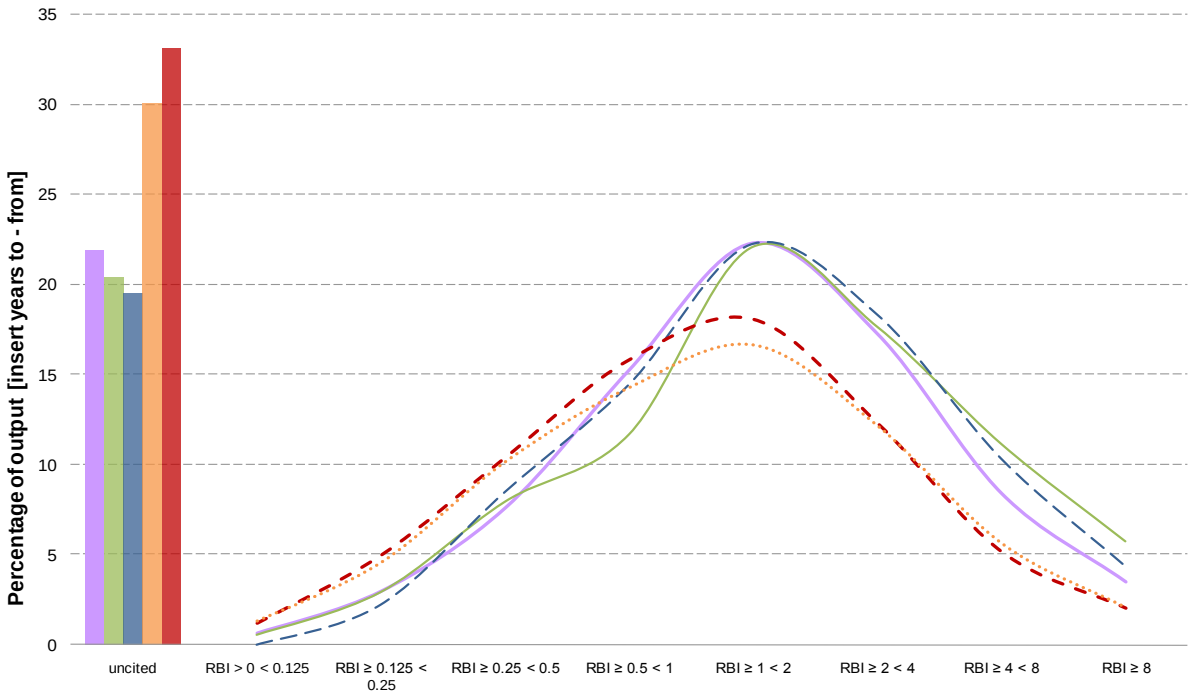
B



C


HEI, all research fields: 46,362 papers
UK, all research fields: 757,172 papers
Percentage of output [insert years to - from]
25
20
15
10
5
0
uncited
mNCI > 0 < 0.125
≥ 0.125 < 0.25
≥ 0.25 < 0.5
≥ 0.5 < 1
≥ 1 < 2
≥ 2 < 4
≥ 4 < 8
mNCI ≥ 8

D


Percentage of output [insert years to - from]
35
30
25
20
15
10
5
0
uncited
RBI > 0 < 0.125
RBI ≥ 0.125 < 0.25
RBI ≥ 0.25 < 0.5
RBI ≥ 0.5 < 1
RBI ≥ 1 < 2
RBI ≥ 2 < 4
RBI ≥ 4 < 8
RBI ≥ 8

A is used to represent the total output of an individual country, institution or researcher with no benchmark data. Visually, it highlights the numbers of uncited papers (weaknesses) and highly cited papers (strengths).

B and **C**: are used to represent the total output of an individual country, institution or researcher (**client**) against an appropriate benchmark dataset (**benchmark**).The data are displayed as either histograms (B) or a combination of histogram and profile (C). Version C prevents the 'travel' which occurs in histograms where the eye is drawn to the data most offset to the right, but this can be less easy to interpret as categorical data.

D illustrates the complexity of data which can be displayed using an Impact Profile®. These data show research output in defined journal categories against appropriate benchmarks: **client, research field X**; **client, research field Y**; **client, research field Z**; **benchmark, research field X+Y**; **benchmark, research field, Z**.

Impact Profiles® enable an examination and analysis of the balance of published outputs relative to world average and relative to a reference profile. This provides much more information about the basis and structure of research performance than is provided by conventionally reported averages in citation indices.

An Impact Profile® shows what proportion of papers are uncited and what proportion are in each of eight categories of relative citation rates, normalised to world average (which becomes 1.0 in this graph). Normalised citation rates above 1.0 indicate papers cited more often than the world average for the field in which that journal is categorised and in their year of publication.

Attention should be paid to:

- the proportion of uncited papers on the left of the chart
- the proportion of cited papers either side of world average (1.0)
- the location of the most common (modal) group near the centre
- the proportion of papers in the most highly cited categories to the right, (≥4 x world, ≥8 x world).

What are uncited papers?

Somewhat surprisingly, many journal papers are never subsequently cited after publication, even by their authors. This accounts for about half the total global output for a typical, recent 10-year period. It is not possible to tell why papers are not cited. It is likely that a significant proportion of papers remain uncited because they report negative results which are an essential matter of record in their field but make the content less likely to be referenced in other papers. Inevitably, other papers are uncited because their content is trivial or marginal to the mainstream. However, it should not be assumed that this is the case for all such papers.

There is variation in non-citation between countries and between fields. For example, relatively more engineering papers tend to remain uncited than papers in other sciences, which is indicative of a disciplinary factor but not a quality factor. While there is also an obvious increase in the likelihood of citation over time, most papers that are going to be cited will be cited within a few years of publication.

What is the threshold for 'highly cited'?

Thomson Reuters has traditionally used the term 'highly cited paper' to refer to the world's 1% of most frequently cited papers, taking into account year of publication and field. In rough terms, UK papers cited more than eight times as often as relevant world average would fall into the Thomson Highly Cited category. About 1-2% of papers (all papers, cited or uncited) typically overcome this hurdle. Such a threshold certainly delimits exceptional papers for international comparisons but, in practice, it is an onerous marker for more general management purposes.

After reviewing the outcomes of a number of analyses, we have chosen a more relaxed definition for our descriptive and analytical work. We deem papers that are cited more often than four times the relevant world average to be relatively highly cited for national comparisons. This covers the two most highly cited categories in our graphical analyses.

Annex 2: Selected *Web of Science*℠ scope notes

Biochemistry & Molecular Biology is concerned with journals that deal with general biochemistry and molecular biology topics such as carbohydrates, lipids, proteins, nucleic acids, genes, drugs, toxic substances, and other chemical or molecular constituents of cells, microbes, and higher plants and animals, including humans. Journals that focus on biochemistry in cells, tissues or organs and those whose primary focus is the organism of study (such as plants, microbes, and so forth) are excluded, as are journals that focus on methods in biochemistry or molecular biology.

Biophysics covers journals that focus on the transfer and effects of physical forces and energy that is light; sound; electricity; magnetism; heat and cold; pressure; mechanical forces and radiation within and on cells, tissues, and whole organisms.

Biotechnology & Applied Microbiology includes journals that deal with a broad range of topics on the manipulation of living organisms to make products or solve problems to meet human needs. Topics include genetic engineering, molecular diagnostic and therapeutic techniques, genome data mining, bioprocessing of food and drugs, biological control of pests, environmental bioremediation, and bio-energy production. This category also covers journals that deal with the related social, business, and regulatory issues.

Cell Biology includes journals on all aspects of the structure and function of eukaryotic cells. The principle characteristic of journals in this category is an emphasis on the integration at the cellular level of biochemical, molecular, genetic, physiological, and pathological information. This category considers material on specific tissues, differentiated as well as embryonic.

Clinical Neurology covers journals on all areas of clinical research and medical practice in neurology. The focus is on traditional neurological illnesses and diseases such as dementia, stroke, epilepsy, headache, multiple sclerosis, and movement disorders that have clinical and socio-economic importance. This category also includes journals on medical specialties such as pediatric neurology, neurosurgery, neuroradiology, pain management, and neuropsychiatry that affect neurological diagnosis and treatment.

Endocrinology & Metabolism includes journals focused on endocrine glands; the regulation of cell, organ, and system function by the action of secreted hormones; the generation and chemical/biological properties of these substances; and the pathogenesis and treatment of disorders associated with either source or target organs. Specific areas covered include neuroendocrinology, reproductive endocrinology, pancreatic hormones and diabetes, regulation of bone formation and loss, and control of growth.

Gastroenterology & Hepatology includes journals on the anatomy, physiology, biochemistry, and pathology of the digestive system. This category includes specific journals on the prognosis and treatment of digestive diseases; stomach ulcers; metabolic, genetic, infectious and chemically induced diseases of the liver; colitis; diseases of the pancreas and diseases of the rectum.

General & Internal Medicine includes journals on medical specialties such as general medicine, internal medicine, clinical physiology, pain management, military and hospital medicine. Journals focusing on family medicine and primary health care services are placed in the Primary Health Care category.

Genetics & Heredity includes journals that deal with the structure, functions and properties of genes, and the characteristics of inheritance. This category also considers heritable traits, population genetics, frequency and distribution of polymorphism, as well as inherited diseases and

disorders of the replicative process. The category is distinguishable from Biochemistry & Molecular Biology by its specific emphasis on the gene as a single functional unit, and on the gene's effect on the organism as a whole.

Haematology covers journals that deal with blood and blood-forming tissues, as well as the functions, diseases and treatments of these systems. Topics included are hemophilia, neoplastic disorders of the blood or lymphoid tissues, and mechanisms and disorders of thrombosis.

Immunology covers journals dedicated to all aspects of immune response and regulation, at the cellular-molecular level as well as the clinical level. Other topics include studies of the interaction between pathogens and host immunity, as well as clinical immunology, emerging immunotherapies, and the immunologic contribution to disease course.

Infectious Diseases includes journals on all aspects of the pathogenesis of clinically significant viral or bacterial diseases including HIV, AIDS, sexually transmitted diseases (STDs). This category is also concerned with journals on host-pathogen interactions, as well as the prevention, diagnosis, treatment, and epidemiology of infectious disease.

Microbiology includes journals dealing with all aspects of fundamental and applied studies of microorganisms, including bacteria, viruses, and fungi. This category also considers journals on the clinical aspects of the occurrence and treatment of microbial pathogens, basic science studies of microbial biochemistry and function, environmental microbiology and bacterial/viral uses in biotechnology.

Neurosciences covers journals on all areas of basic research on the brain, neural physiology, and function in health and disease. The areas of focus include neurotransmitters, neuropeptides, neurochemistry, neural development, and neural behavior. Coverage also includes journals in neuroendocrine and neuroimmune systems, somatosensory system, motor system and sensory motor integration, autonomic system as well as diseases of the nervous system.

Oncology covers journals on the mechanisms, causes, and treatments of cancer, including environmental and genetic risk factors, and cellular and molecular carcinogenesis. Aspects of clinical oncology covered include surgical, radiological, chemical, and palliative care. This category is also concerned with journals on cancers of specific systems and organs.

Peripheral Vascular Disease covers journals on arterial occlusive disease (atherosclerosis or hardening of the arteries); venous obstruction and clotting; venous incompetence/insufficiency; cerebrovascular disease; aneurysms; vasospastic disorders, and other vascular disorders. This category also covers hypertension, circulation, and stroke. Journals on the diagnosis, treatment, and prevention of heart diseases are covered in the Cardiac & Cardiovascular Systems category.

Pharmacology & Pharmacy includes journals on the discovery and testing of bioactive substances, including animal research, clinical experience, delivery systems, and dispensing of drugs. This category also includes journals on the biochemistry, metabolism and toxic or adverse effects of drugs.

Psychiatry covers journals that focus on the origins, diagnosis, and treatment of mental, emotional, or behavioral disorders. Areas covered in this category include adolescent and child psychiatry, forensic psychiatry, geriatric psychiatry, hypnosis, psychiatric nursing, psychiatric rehabilitation, psychosomatic research, and stress medicine.

Public, Environmental & Occupational Health includes journals dealing with epidemiology, hygiene, and health; parasitic diseases and parasitology; tropical medicine; industrial medicine; occupational medicine; infection control; and preventive medicine. Also included are journals on environmental health; cancer causes and control; aviation, aerosol, and wilderness medicine.

Research & Experimental Medicine includes journals describing general medical research with a particular emphasis on extremely novel techniques and clinical interventions in a broad range of medical specializations and applications, including vaccine development, tissue replacement, immunotherapies, and other experimental therapeutic strategies. Journals in this category reflect clinical interventions that are in early stages of development, using in vitro or animal models, and small-scale clinical trials.

Annex 3: *Web of Science*℠ journal categories

Acoustics	Classics	Engineering, multidisciplinary
Agricultural economics & policy	Clinical neurology	Engineering, ocean
Agricultural engineering	Communication	Engineering, petroleum
Agriculture, dairy & animal science	Computer science, artificial intelligence	Entomology
Agriculture, multidisciplinary	Computer science, cybernetics	Environmental sciences
Agriculture, soil science	Computer science, hardware & architecture	Environmental studies
Agronomy	Computer science, information systems	Ergonomics
Allergy	Computer science, interdisciplinary applications	Ethics
Anatomy & morphology	Computer science, software engineering	Ethnic studies
Andrology	Computer science, theory & methods	Evolutionary biology
Anaesthesiology	Construction & building technology	Family studies
Anthropology	Criminology & penology	Film, radio, television
Applied linguistics	Critical care medicine	Fisheries
Archaeology	Crystallography	Folklore
Architecture	Dance	Food science & technology
Area studies	Demography	Forestry
Art	Dentistry, oral surgery & medicine	Gastroenterology & hepatology
Asian studies	Dermatology	Genetics & heredity
Astronomy & astrophysics	Developmental biology	Geochemistry & geophysics
Automation & control systems	Ecology	Geography
Behavioural sciences	Economics	Geography, physical
Biochemical research methods	Education & educational research	Geology
Biochemistry & molecular biology	Education, scientific disciplines	Geosciences, multidisciplinary
Biodiversity conservation	Education, special	Geriatrics & gerontology
Biology	Electrochemistry	Health care sciences & services
Biology, miscellaneous	Emergency medicine	Health policy & services

Biophysics	Endocrinology & metabolism	Haematology
Biotechnology & applied microbiology	Energy & fuels	History
Business	Engineering, aerospace	History & philosophy of science
Business, finance	Engineering, biomedical	History of social sciences
Cardiac & cardiovascular systems	Engineering, chemical	Horticulture
Cell biology	Engineering, civil	Humanities, multidisciplinary
Chemistry, analytical	Engineering, electrical & electronic	Imaging science & photographic technology
Chemistry, applied	Engineering, environmental	Immunology
Chemistry, inorganic & nuclear	Engineering, geological	Industrial relations & labour
Chemistry, medicinal	Engineering, industrial	Infectious diseases
Chemistry, multidisciplinary	Engineering, manufacturing	Information & library science
Chemistry, organic	Engineering, marine	Instruments & instrumentation
Chemistry, physical	Engineering, mechanical	Integrative & complementary medicine
International relations	Mining & mineral processing	Psychology
Language & linguistics	Multidisciplinary sciences	Psychology, applied
Language & linguistics theory	Music	Psychology, biological
Law	Mycology	Psychology, clinical
Limnology	Nanoscience & nanotechnology	Psychology, developmental
Linguistics	Neuroimaging	Psychology, educational
Literary reviews	Neurosciences	Psychology, experimental
Literary theory & criticism		Psychology, mathematical
Literature	Nuclear science & technology	Psychology, multidisciplinary
Literature, African, Australian, Canadian	Nursing	Psychology, psychoanalysis
Literature, American	Nutrition & dietetics	Psychology, social
Literature, British Isles	Obstetrics & gynaecology	Public administration
Literature, German, Dutch, Scandinavian	Oceanography	Public, environmental & occupational health
Literature, romance	Oncology	Radiology, nuclear medicine & medical imaging
Literature, Slavic	Operations research & management science	Rehabilitation

Management	Ophthalmology	Religion
Marine & freshwater biology	Optics	Remote sensing
Materials science, biomaterials	Ornithology	Reproductive biology
Materials science, ceramics	Orthopaedics	Respiratory system
Materials science, characterization & testing	Otorhinolaryngology	Rheumatology
Materials science, coatings & films	Palaeontology	Robotics
Materials science, composites	Parasitology	Social issues
Materials science, multidisciplinary	Pathology	Social sciences, biomedical
Materials science, paper & wood	Paediatrics	Social sciences, interdisciplinary
Materials science, textiles	Peripheral vascular disease	Social sciences, mathematical methods
Maths & computational biology	Pharmacology & pharmacy	Social work
Mathematics	Philosophy	Sociology
Mathematics, applied	Physics, applied	Soil science
Mathematics, interdisciplinary applications	Physics, atomic, molecular & chemical	Spectroscopy
Mechanics	Physics, condensed matter	Sport sciences
Medical ethics	Physics, fluids & plasmas	Statistics & probability
Medical informatics	Physics, mathematical	Substance abuse
Medical laboratory technology	Physics, multidisciplinary	Surgery
Medicine, general & internal	Physics, nuclear	Telecommunications
Medicine, legal	Physics, particles & fields	Theatre
Medicine, research & experimental	Physiology	Thermodynamics
Medieval & renaissance studies	Planning & development	Toxicology
Metallurgy & metallurgical engineering	Plant sciences	Transplantation
Meteorology & atmospheric sciences	Poetry	Transportation
Microbiology	Political science	Transportation science & technology
Microscopy	Polymer science	Tropical medicine
Mineralogy	Psychiatry	
Urban studies		

Urology & nephrology		
Veterinary		
Veterinary sciences		
Virology		
Water resources		
Women's studies		
Zoology		