evidence

Research strengths in Ireland:
a bibliometric study of the
public research base

November 2009

Forfás

HEA
Higher Education Authority
An tÚdarás um Ard-Oideachas

This report was commissioned by Forfás and the Higher Education Authority (HEA). For further information contact:

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Introduction

The client

Forfás and the Higher Education Authority (HEA) have commissioned this report as part of an assessment of research activity in Ireland. This is a mapping exercise that takes stock of Ireland's activity in research across all disciplines so as to provide an informed catalogue of research activity.

The Irish Government's Strategy for Science Technology and Innovation (SSTI) outlines steps that Ireland is expected to take to develop a world class research system. Critical to the success of the SSTI is the degree to which the outputs (people with world class education, ideas, knowledge) of this investment are relevant to and impact on the enterprise base. The SSTI provides mechanisms for the transfer of knowledge from research organisations and higher education institutions (HEIs).

Against this background, it is proposed to map existing and emerging fields of research activity and strengths in higher education (HE) and other public research institutions. The public research base is understood, for the purpose of this study, to comprise both HEIs and other public-sector research organisations. Although the latter are not discussed in this report they interact extensively; for example: through clinical medical units. This mapping study will fit within a broader programme of work on the effectiveness of the SSTI "ecosystem" in Ireland and complement related initiatives.

The report

The report opens with a thematic overview which includes an executive summary. This can be read on its own or as an introduction to the body of the report. The overview is followed by a detailed explanation of the methodology. The body of the report is the detailed series of tables and figures illustrating the analytical outcomes, with interpretive commentary on each indicator. The analysis is developed in themes arranged in four sections:

1. International Comparative Performance of the Irish research base at overall system, broad subject and finer disciplinary levels (pages 1-63).

2. Institutional Comparative Research Performance in Ireland and Northern Ireland (pages 64-99).

3. Research Collaboration internationally and within the island of Ireland (pages 100-102).

4. Impact Profiles® describing the distribution of citation impact underpinning Ireland's average relative performance (pages 103-109).

The analysts

Evidence Ltd, a wholly owned subsidiary of Thomson Reuters, has carried out the analyses and produced this report. It has considerable experience in related work for a number of jurisdictions and has ready data and appropriate and tested methodology to address these requirements. It is currently producing reports of a similar nature for both Brazil and for Scotland.

Evidence specialises in research performance analysis and interpretation. It has extensive experience with and databases on research inputs, activity and outputs relating to research both globally and particularly for the European research base. It has also developed innovative analytical approaches for benchmarking international, national and institutional research impact.

Evidence works for UK and European government departments and agencies and for universities and other research-based organisations. *Evidence* staff have experience in research institutes, HE research management and administration, national policy development and both private sector and charitable research organisations.

Thematic overview

Executive summary

This report makes use of bibliometric analyses of research performance. Bibliometrics are about publication data and the rates of citation (cross-reference) between those publications. It is generally agreed that more frequently cited papers are associated with other measures of excellent research and can be used as a proxy indicator for research quality.

The published output of the research base in Ireland has grown rapidly, more than doubling between 1998 and 2007 (Figure 1). For comparison, output for G7 countries was roughly level. Recent growth has been around 33% compared with less than half this for a diverse group of comparator countries reported here (see **Background**). Nonetheless, the total research capacity remains small and most growth was in Higher Education Institutions (HEIs).

Ireland typically takes a 0.3-0.4% share of world papers. (Indicator 1.01) In biological sciences, where growth is strong, its share is higher (around 0.5%) and much higher in agriculture (0.6%) and agricultural biotechnology (1.5%). It also does well in computer science and electronic engineering, although these areas make strong use of non-journal outputs. (Indicators 1.02 and 1.03) In some areas its research growth has been less rapid than for other expanding comparator countries, so its output and citation volume increases but its rank falls but without affecting the trend for improving citation impact

Ireland's share of world citations is greater than its share of world papers (0.49% recently, 0.64% in 2007: Indicator 1.04) so its output is cited more than average. Consequently, Ireland's citation impact is good and improving. Whereas it ranks 18th by volume, it ranks 8th on citation impact overtaking Australia and Finland. However, note that 1998, the first year in the analysis, was a peak and if 1999 been the starting point then relative improvement would have seemed greater! (Indicator 1.05) At subject level, health research and physical sciences perform well. Competition in biological sciences constrains relative performance but agricultural biotechnology is stronger. Citation impact in physics & materials and in chemistry is rising and nanotechnology is above average. (Indicators 1.06 and 1.07) Because

of the exceptional peak in the first year, its 98-07 rank has fallen in one or two areas but its recent trend is clearly upwards.

The research base is dominated by UCD (now similar in volume to QUB), TCD and UCC. (Indicator 2.01) The picture is of a small number of HEIs which support diverse portfolios and have grown rapidly, supported by a network of medium-sized and smaller institutions with niche competitive research. Citation impact has increased for many HEIs. TCD has been a consistent leader, but UCD has improved by a greater margin, overtaking QUB, while RCSI and DIAS have exceptional profiles. (Indicator 2.05)

In biological sciences, TCD retains a clear lead on citation impact though UCD has improved. In environmental sciences, citation impact is above world average for the four main HEIs. In physical sciences TCD has a strong and consistent position on citation impact, early and late, but UCD has recently shown an exceptional improvement in physics & materials sciences. Engineering output is concentrated in electrical engineering, TCD has good overall citation impact but UCD has a clear lead in the electronic engineering area, whilst UCC has expanded rapidly at some cost to citation impact. (Indicators 2.06 and 2.07)

International collaboration is rising. Ireland's strong links to the USA are less than for some comparator countries. Its collaboration is increasing more for mainland Europe than for the UK, and more for Asia/Pacific than Europe. (Indicator 3.01) HEI international links show contrasting patterns. UCD has more collaboration with mainland Europe, especially the Netherlands, and China. TCD has more activity with Australia and Japan. (Indicator 3.02) Inter-institutional collaboration is relatively low and collaboration with Northern Ireland is very low compared to typical inter-institutional collaborative links in other countries. QUB links to 1% of output for UCD and 2% for TCD whereas QUB and UU share 10% of the latter's activity. Collaboration between TCD and UCD is less than 3%. (Indicator 3.03)

Ireland has more uncited papers than leading research economies but the modal cited group is above world average. It also has a good balance of excellence with 6.2% of papers cited more than four times as often as world average, which compares with 6.1% for the UK. (Indicator 4.01) Across

research areas, the analysis suggests that national and institutional impact depends on a relatively small peak of activity. In molecular biology and biotechnology, where citation impact has dropped recently, the modal cited group is above world average but there are few papers in the most highly cited groups. Ireland is not building from the strong platform into higher levels of excellence. In physics, an area with a high overall average, the modal group is below world average so the Irish average must be drawn up by a small core of excellence. Electronic engineering also has a narrow peak of exceptional performance. (Indicator 4.02)

1 – International comparative research performance

There has been a very rapid growth in the research base for Ireland, as measured by the volume of research articles and reviews published in journals indexed on the Thomson Reuters 'Web of Science' global database of 10,000 of the most highly cited serials. Ireland's volume output more than doubled between 1998 and 2007 but, for comparison, the output of France, Germany and the UK was roughly level over the same period.

Figure 1: The recent growth of research output for Ireland
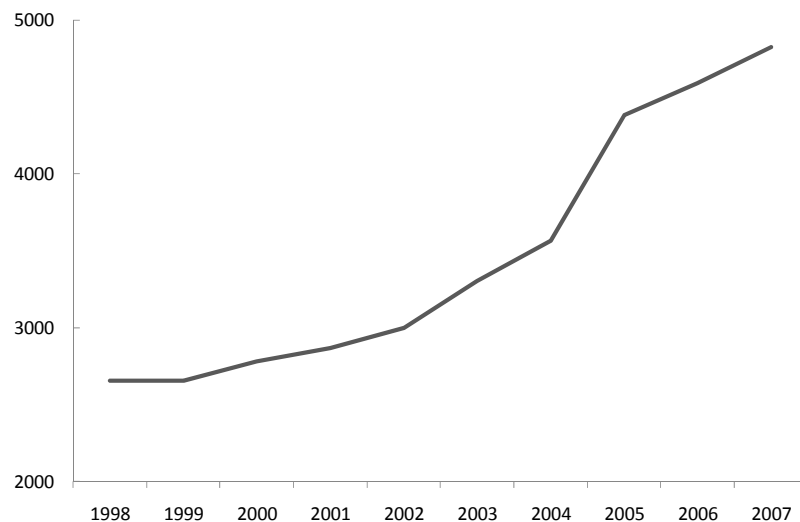
Average recent growth (2007 compared with the average of the five years 2002-2006) has been around 33% compared with 14% for the comparator group as a whole. The greatest part of the publication growth was in the Universities, Institutes of Technology and Colleges (Higher Education Institutions, HEIs), since these naturally tend to disseminate their research outcomes through a publication route. However, the health sector, public laboratories and commercial R&D enterprises will also have contributed to the underlying profile.

The first part of the study explored the disciplinary portfolio that contributed to this growth and examined the academic impact of Ireland's research. Impact is conventionally measured in terms of the number of times a paper is subsequently used and cited by other researchers (see later sections for background on *bibliometrics*).

Indicator 1.01 (page 1) analyses the total output for Ireland and comparator countries.

Indicators 1.02 (pages 2-11) analyse national output across ten major fields.

Indicators 1.03 (pages 12-31) analyse national output across twenty "project" research areas created for this project. There is some overlap in category labelling but the data are mapped differently between the major and "project" areas.

Growth in output in the biological sciences has been relatively strong at 35-40% in organismal and molecular biology and in biotechnology. This compares with somewhat lower growth rates in the physical sciences but higher growth rates in engineering, driven primarily by growth in electrical and electronic engineering.

These growth rates are important information, because the total capacity of the research base in Ireland remains small. It is one of the smallest nations in the comparator group (a full list is given in the Background section below), a position which may not change greatly in the near future because other similar-sized comparators are often equally dynamic.

Ireland typically takes a 0.3-0.4% share of world papers. In biological sciences its share is higher (around 0.5%) and much higher in agriculture (0.6%) and agricultural biotechnology (1.5%). It also does well in computer

science and electronic engineering, although these areas make strong use of non-journal outputs.

Indicator 1.04 (page 32) analyses the total citation count to published papers for Ireland and comparator countries.

Ireland's share of world citations is greater than its share of world papers (0.49% recently, 0.64% in 2007) so its output is cited more than is typical within the comparator group.

Indicator 1.05 (page 33) analyses overall average citation impact (citations per paper) for Ireland and comparator countries.

As a consequence of its strong relative share, Ireland's citation impact is very good and it is also improving following a marked dip in 2000. Whereas it ranks 18th in share by volume, it ranks 8th in the group on citation impact. It has overtaken Australia and, recently, Finland in overall national citation impact. For the size of its research base this must be seen as an exceptional achievement for Ireland.

Indicators 1.06 (pages 34-43) analyse citation impact across ten major fields.

Indicators 1.07 (pages 44-63) analyse citation impact across twenty "project" research areas. There is some overlap in category labelling but the data are mapped differently between the major and "project" areas.

At subject level, Ireland appears to be doing well in health research and in physical sciences. In biological sciences, the level of competition is such that despite its strong share it is not improving at the same rate as competitors but its position in agricultural biotechnology is stronger.

In the physical sciences, Ireland's research in physics & materials and in chemistry performs very well and is on a rising trajectory. In nano-technology, its performance is above average but the competition is again very substantial.

2 – Institutional comparative research performance

The aggregate annual output of Ireland's HEIs is shown in Table 1 below. This lists all the institutions for which data have been tracked, although not all of these are subsequently analysed.

Table 1 reveals the extent to which the research base is dominated by three larger institutions: University College Dublin (UCD); Trinity College (TCD); and University College Cork (UCC). Each of these has grown rapidly in the last decade and UCD is now similar in output to Queen's University Belfast (QUB), which was considerably the larger before 2000.

In the next size group are NUI Galway (NUIG) and Dublin City University, (DCU) which are approaching the University of Ulster (UU) in size. These are followed by a third group with the University of Limerick (UL), the National University of Ireland Maynooth (NUIM) and Dublin Institute of Technology (DIT) but no other institution approaches an output of 100 journal papers per year. There are, however, important 'mono-technics' such as Dublin Institute for Advanced Studies (DIAS) which have less total but concentrate their activity in a niche area.

The picture is therefore of a small number of major institutions which can support diverse portfolio and which have grown much more rapidly than their regional neighbours in Northern Ireland, supported by a network of medium-sized and smaller institutions which are likely to support only select research areas at internationally competitive levels.

Indicator 2.01 (page 64) analyses the total output, summarised across all research fields, for each of the ten largest HEIs and for QUB and UU.

Indicators 2.02 (pages 65-74) analyses output for each HEI across ten major fields.

Indicators 2.03 (pages 75-81) analyses output for each HEI across seven selected "project" research areas. Only seven of the twenty customised "project" research areas had sufficient volume for multiple HEIs to support an informative disaggregation.

The output of most Irish HEIs has increased consistently and for some institutions this has meant a near-doubling over the ten years as a whole. Growth rates are somewhat less for the largest institutions, because they are already relatively productive so a further increase may be more challenging.

Indicator 2.04 would cover raw citation counts but is omitted as the information is more effectively conveyed as citation impact (citations per paper). Numbering for subsequent sections is maintained to enable comparison with international Indicators

Indicator 2.05 (page 82) analyses the citation impact, averaged across all research fields, for each HEI.

Indicators 2.06 (pages 83-92) analyse citation impact across ten major fields.

Indicators 2.07 (pages 93-99) analyses citation impact across the seven selected "project" research areas reported in Indicators 2.03.

For most HEIs the citation impact of their publications has also increased, so they have improved relative to world averages. TCD has been a consistent leader over the decade, but UCD has improved by a greater margin, overtaking QUB, while the Royal College of Surgeons in Ireland (RCSI) and DIAS have an exceptional profile of change. UCC had a marked drop early in the period, but UL declined progressively throughout.

In clinical sciences, the improving and lead position on citation impact for TCD and RCSI is clear but NUIG has also improved.

Biological sciences is an area of significant volume and growth for UCD, whereas growth is less marked for TCD. There is exceptional relative volume for UCC, though less relative growth, but it nonetheless has greater output than QUB and TCD. Despite its smaller volume, TCD retains a clear lead on citation impact though UCD, however, has substantially improved its citation impact in this globally competitive area, as has RCSI.

In environmental sciences, citation impact has improved from below to above world average for the four main Ireland HEIs in this area. This contrasts with Northern Ireland where citation impact has fallen for QUB despite its greater capacity.

Physical sciences require substantial, well-established facilities and are often dominated by larger and older institutions, so the relative volume for DCU and DIAS is notable. The four larger Ireland HEIs exhibit marked growth, rather ahead of their institutional averages (the output for DIAS in this area is more than half its total volume). TCD has a strong and consistent position on citation impact, early and late, but UCD has a marked improvement and QUB also improves on a good citation impact base. DIAS, for which this is the key focus, has very strong citation impact and improvement.

Engineering output is concentrated in electrical engineering and publication volumes in civil and mechanical engineering are very low. Bibliometric impact is a weak indicator of performance in engineering research. Nonetheless, TCD and UCD and QUB have good and improving citation impact on their volume while UCC has expanded rapidly at some cost to citation impact. RCSI has exceptional citation impact on a tiny volume, as in physical sciences. Many institutions vary around world average, a pattern seen in other jurisdictions where many engineering units have a mixed pure and applied portfolio.

3 – Collaboration

The co-authorship analyses for Ireland show:

- Rapidly rising collaboration profiles
- Very good links with the USA
- Potentially strong links within Europe, varying between institutions and therefore likely built on specific initiatives
- A need to foster links with China and perhaps other targets in Asia
- A relatively poor level of collaboration within Ireland, with some notable exceptions
- Very little collaboration with Northern Ireland

Indicator 3.01 (page 100) considers international collaboration for the whole of the Ireland HE sector across all research fields.

International collaboration is rising at a significant rate. Ireland has strong links to the USA, which should be carefully strengthened. About 400 papers per year or roughly 10% of total output are collaborative with the USA and a similar number with England. That is less than for the UK itself, for which over 40% of publications are collaborative, but not massively so. The UK's collaboration with the USA accounts for about 12-15% of its total output. For Ireland, the balance between the UK, France and Germany is unusual within the EU. Collaboration is now increasing more for mainland Europe than for the UK, however, and more for Asia/Pacific than Europe.

Doubling links with many leading research countries in Europe will provide excellent links to support further research growth for Ireland and keep activity at the forefront of EU initiatives. The attractiveness of the UK as a nearest-neighbour with a common language should not outweigh the intellectual benefits of other partners.

Indicator 3.02 (page 101) considers international collaboration by partner country for individual Ireland HEIs, with QUB and UU, across all research fields.

Institutions' international links show contrasting patterns. QUB has strong links with other UK regions while UCD has more collaboration with mainland Europe. There are similar volumes with the USA. TCD has more activity with Australia and Japan than does UCD while the latter has many more links with Netherlands and China. Many of the smaller institutions also have surprising levels of collaboration with the USA and this clearly underpins the national pattern. For China, however, the level of collaboration is still low, especially compared to Northern Ireland.

Indicator 3.03 (page 102) considers inter-institutional collaboration for individual Ireland HEIs and with QUB and UU.

The level of national inter-institutional collaboration is relatively small. Collaboration between Ireland and Northern Ireland is very low, with QUB linking to around just 1% of output for UCD and about 2% of output for TCD whereas collaboration between QUB and UU is over 10% of the latter's activity. That compares with the collaboration between TCD and UCD of less than 3%. Given the spread of activity and inevitable demand for resources, these data suggest that there is much latent potential for collaboration.

4 – Impact Profiles®

Indicator 4.01 (page 103) illustrates the overall Impact Profile® for Ireland, allotting papers into eight bins by citation impact relative to world average.

Indicators 4.02 (page 104-109) illustrates Ireland's Impact Profile® for six select project research areas.

The distribution of citation impact by category compared to world average shows that Ireland has slightly more uncited papers than is typical for leading research economies but the modal cited group is above world average. It also has a good balance of excellence with 6.2% of papers cite more than four times as often as world average, which compares with 6.1% for the UK.

Impact is also profiled for six select project research areas. The analysis across these categories suggests that the outcomes seen for sections 1 (national) and 2 (institutional) citation average citation impact indicators depend on the make-up of the relatively small percentage of papers in the most highly cited categories.

The Impact Profile® in clinical medicine is shifted towards lower impact categories than the overall national profile so the percentage above world average is slightly lower than the national average across all subjects. The spread suggests that Ireland's average citation impact is influenced by the relatively small share of very highly cited papers. In molecular biology and biotechnology, average citation impact has dropped in recent years. The profiles show that while the modal group among cited papers is above world average, so the profile initially appears strong, there are relatively few papers in the more highly cited groups. Ireland is not building from the strong platform into higher levels of excellence.

By contrast, in physics the modal group is below world average but the overall balance is similar to the national profile. Since average citation impact is high, the average must be drawn up by the small group of excellent papers at the high citation impact end. Electronic engineering has a rather different profile, but one typical of engineering fields. However, the percentage of papers cited more than 4 times world average is higher than the national average so there seems to be a narrow peak of exceptional performance. Economics & business produces a uniquely bimodal distribution. This suggests a split between a group of relatively high performing units and other units with much less internationally competitive research.

Table 1. Institutional output volume for higher education institutions in Ireland and Northern Ireland

Data coverage on Thomson Reuters' Web of Science databases. Address variants supplied by the institutions via the HEA. Address aggregation by *Evidence* Ltd.

Institution Name	Code	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Total articles
University College Dublin	UCD	527	519	569	621	625	693	804	960	974	1079	7371
Trinity College Dublin	TCD	463	492	539	486	573	656	671	834	851	892	6457
University College Cork	UCC	367	418	405	479	489	494	553	655	750	765	5375
NUI Galway	NUIG	226	202	205	204	228	266	278	338	413	397	2757
Dublin City University	DCU	173	169	146	143	152	175	230	278	309	353	2128
University of Limerick	UL	81	79	102	133	129	202	204	271	224	224	1649
NUI Maynooth	NUIM	61	70	103	92	104	128	137	198	193	186	1272
Royal College of Surgeons in Ireland	RCSI	78	93	78	91	89	111	110	138	149	147	1084
Dublin IT	DIT	35	49	75	74	51	68	84	99	126	118	779
Dublin Institute for Advanced Studies	DIAS	55	42	40	46	42	40	62	84	84	73	568
Queens University Belfast	QUB	886	896	985	927	837	990	1010	1189	1024	1157	9901
University of Ulster	UU	298	289	374	336	333	369	401	443	461	462	3766

A number of other higher education institutions are present in the underlying database. None of them has more than 500 indexed papers in total over the ten-year period and they have therefore been excluded from individual analyses as the outcomes would be statistically unreliable.

Bibliometrics and citation analysis

Bibliometrics are about publications and their citations. The field has emerged from information science and refers to analyses and methods used to study and index texts and information.

Publications cite and are cited by other publications. This provides linkages and networks. Many links are likely to be related to significance or impact. Meaning is determined from keywords and content. Citation analysis and content analysis are therefore commonly used bibliometric methods. Historically, bibliometric methods had been used to trace relationships amongst academic journal citations. Bibliometrics now are increasingly important in indexing research performance. Bibliometric data have particular characteristics of which the user should be aware, and these are considered here.

The origins of citation analysis as a widespread tool of 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 & Humanities Citation Index, produced by the Institute of Scientific Information (now Thomson Reuters Scientific).

The data sources used for this report are the Thomson Reuters databases, a single source collated to the same standard and therefore providing a level of comparability not found in other data. The data are also valuable because they can be readily disaggregated by field, by year, by country and by institution.

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', interpreted as significance or influence in 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.

Most impact measures 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.
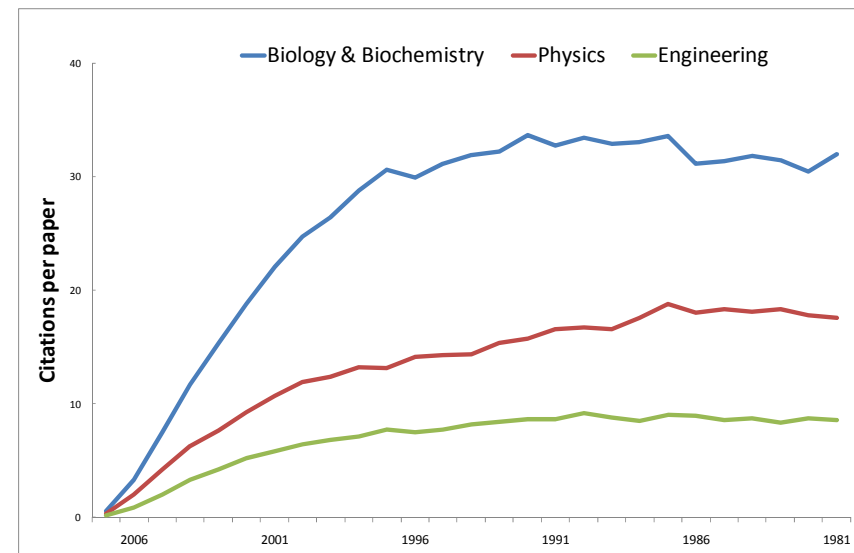
Time factors

Citations accumulate over time. Older papers therefore have, on average, more citations than more recent work. Figure 2 shows the pattern of citation accumulation for several disciplines. Papers less than eight years old are, on average, still accumulating additional citations. Only for older sources has the citation count plateaued.

The percentage of papers that have never been cited drops over about five years. Beyond five years, some 10% or more of papers continue 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.

Figure 2. Average citation counts for successively older papers

Discipline factors

Figure 2 also shows that citation rates vary between disciplines and fields. For the national research base as a whole, ten years 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 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 categories are well established and are informed by extensive work by Thomson Reuters and with the research community over the last quarter century. 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. However, some papers are not assigned to any research field and will not be included in specific analyses. The Multidisciplinary research field may include prestigious journals such as *Nature* and *Science*. Most papers from these 'multidisciplinary' journals are assigned to more specific research fields, however, based on the research area(s) of the references cited by the article.

Rebased impact

For the reasons given above, 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. The common normalisation factor is average citations per paper for the year and either the field or journal in which the paper was published.

This normalisation is also referred to as 'rebasing' the citation count. Citation impact is therefore commonly discussed in terms of 'rebased' citation impact, labelled RBI.

Average impact

The distribution of citations amongst papers is highly skewed – many papers are uncited and a very few papers have high citation counts. Historically, research performance has been indexed using average citation impact (rebased as described to world average to standardise for time and discipline).

This average may be misleading, however, when assumptions are made about the distribution of the data beneath it. Almost all research activity metrics are skewed: many low performance values and a few exceptionally high values. In reality, therefore, the average citation impact tends to be significantly different from either the median or mode in the underlying distribution.

Impact Profiles[®]

Evidence Ltd has developed a bibliometric methodology[1] to reveal 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. 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 defined as those with a rebased citation impact (RBI) 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. For the USA and the UK, about 6-8% of papers pass this threshold.

The proportion of uncited papers in a dataset can be compared to a benchmark. As many as 35% of world research publications may remain uncited in a typical ten-year sample, even for leading research economies.

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

Data source

This study has used data drawn from Thomson Reuters' Web of Science (WoS). This has a well understood and validated structure, provides an historical depth that supports national trend analysis and has an authoritative focus on high-quality publications. But it is not the only possible source.

Bibliographic data (records of published items) are potentially retrievable from many sources including learned society archives, institutional repositories and from Google Scholar. These can, collectively, provide a diverse collation, although bringing all this to a common standard and deduplicating the records is potentially onerous.

For bibliometric analysis (indexing the citations to publications), there are two main commercial data sources: Thomson Reuters' well established WoS; and the relatively new Scopus, from Elsevier. These both have transparent criteria for the material they cover, principally journal articles and now also conference proceedings, and have been created in response to broadly similar markets, so their coverage has a great deal in common.

WoS has been available since the 1980s and is a familiar search-tool for most academic researchers while it is only recently that its monopoly position has been challenged by Scopus. Therefore, one immediate difference between the two databases is that WoS has much greater historical depth. As well as its fully-indexed core material which runs back into the 1970s, WoS has been indexing references from that to earlier material for its 'Century of Science' and recently released 'Century of Social Science'. Thus, for longer time-based analyses, WoS has a clear advantage.

Scopus has set out to compete with WoS by offering a greater spread to its coverage. This is partly regional, because WoS has had an Anglophone and trans-Atlantic focus, and partly subject based, because WoS has had deficits in the social sciences, where journals have historically been less important. It is also said to be more comprehensive, or less selective, in its coverage policy and includes more 'second tier' journals than WoS.

The less selective coverage of Scopus appears to produce some initially surprising but explainable consequences. Adding papers from less frequently cited journals increases the total number of items attributable to some organisations without increasing their citation count proportionally. Thus their 'coverage' is better but their relative 'impact' (average citations per paper) drops. For organisations (and countries) with a greater proportion of output in lower impact journals the drop is relatively greater, so the differentiation between the good and the average may increase.

On a subject level, work in Australia, the Netherlands and the UK has suggested that WoS remains the better choice for information on core physical sciences, biomedicine and – perhaps – engineering. Scopus appears to have better coverage in health sciences, technology and information science and in social sciences. Neither is strong in arts and humanities, but that is essentially because those fields remain strongly wedded to professional media and monographs rather than journals as a key mode of communicating research outcomes to users. For research performance analysis, where historical analysis is important, then WoS must be preferred. Many scientometric analysts are presently engaged in comparative studies and these will in due course help to unpack differences and comparative benefits.

In practice, the initial differences between the two databases may become increasingly blurred. Thomson is responding to competition. It has increased WoS regional coverage with a significant recent increase in both European non-Anglophone journals and a wider range of Asia and Asia-Pacific journals. It has extended coverage to include the Chinese Science Citation Index, although this is not yet integrated into its core products. It has also taken the previously separate system for indexing leading conference series and has incorporated this as core material within WoS. Thomson also has a depth of evaluation methodology based on its long experience in using the data.

Scopus started out with very good coverage of conference proceedings but, meanwhile, is understood to have actually become more selective in journal coverage, recognising that the cost of indexing many infrequently cited journals was not balanced by a sufficient demand to access their contents. It has also encountered inevitable teething problems with, for example, address reconciliation (collating name variants used by authors to identify their organisation) which may be corrected in later versions.

It seems reasonable to expect that both providers will continue to develop and sharpen the information content of their products over the next few years. This is extremely good news for users. There will be a progressively richer range of data on which to draw, with much improved tools for both searching and analysing the material.

For the corporate or government customer, decisions about investment are likely to need to be tuned to specific purpose. The characteristics of the data sources are in flux as they compete and develop, and differences between them may change quite rapidly as new features or content are released. Evaluation of the relative benefits of each source will need to be re-done as part of due diligence for each new purpose.

Background

Forfás and the HEA rightly expect that a number of different sources of information about research and development activity and performance would need to be employed to deliver the required outputs for their overall scope. They anticipate that the methods, indicators and metrics used here will yield both quantitative and qualitative outputs that will address the objectives set out above, focussing particularly on the phase of knowledge generation which underpins innovation and development.

This report concentrates on bibliometrics, for which Forfás and the HEA are aware of limitations. They have stated that they do not plan to use the bibliometric results in isolation but to deploy them in conjunction with results on research funding and numbers of researchers, PhD students and research staff and with other qualitative information. This will be important in relating these analyses to effectiveness and efficiency measures, such as per capita productivity

Indicators

A wide variety of indicators can be used to index different aspects of quantity and quality for journal article data. Many are tried and tested, and some innovative methodologies are now available, but some of these are most appropriate at the more detailed levels associated with targeted studies on particular disciplines or organisations.

For national comparisons, *Evidence* has found that an initial report should make use of relatively high-level, generic indicators. These are simple and transparent and accessible to a general policy audience. Once the outcomes of these initial studies have been absorbed and accepted it may then be valuable to move into more detailed areas and more complex analyses with confidence.

The research process is best described by a combination of input, activity and output variables. However, only the last of these leads directly to an index of quality. While relative ability to acquire income is clearly a reflection of track record and good ideas, there is great variation in cost and in access to funding between fields and between jurisdictions, and this throws out any

direct measure. Staff and training variables are similarly affected by non-quality factors.

Consequently, most international comparative studies make extensive use of bibliometrics. The basic elements in bibliometrics are counts of journal articles and counts of citations to those articles. Citations are references made subsequently to earlier publications. More highly-cited work is regarded as having greater influence or 'impact' on its field and citation impact is, in large samples, equated with relative quality.

Citation rates vary between fields and citations increase over time. For this reason, the count of citations for any single article is meaningless. However, if citation counts for an article are compared to the average for the year and the field to which the journal is assigned then they acquire information through context. By rebasing or 'normalising' individual citation counts against relevant world averages for large samples of articles we can obtain good indicators for policy purpose. This index is the 'citation impact' referred to in this report.

The indicators widely accepted as robust options in other international studies (OECD reports, EC S&T indicators, USA-NSF etc), are broadly employed in this report.

Methodology

The key issues with any research data analysis – including bibliometrics – are time, place and subject. When was the item published? Where is the author located? And to what field is the journal assigned?

The data source for the work was the databases in Thomson Reuters® Web of Science (WoS) raw tagged files, the National Science Indicators (aggregate data), the Ireland and UK National Citation Reports (record level data) and customised data extracts required for purpose.

Methodology: time

Forfás and the HEA have proposed an analysis over a ten-year period. For a census date of 2007, the census period would cover calendar 1998-2007.

Bibliometric data are most readily assigned to whole calendar years, either through the cover year of the publication or the database year of the data supplier. An issue arises if the latter is used, because not all database years cover precisely 12 calendar months, but this is addressed by normalisation of data within year.

Data for 2008 were not available until later in 2009, and the associated citation data would inevitably initially be sparse. By contrast, the data for 2007 publications were already available and are more 'informed' (by citation attribution) than the most recent publications.

Analyses by year are entirely feasible and provide a good sense of trend, but a longer term overview is also possible. For timeliness, two indices are employed as a measure of recent change.

> Graphically, data are presented either (i) by year for a ten-year period 1998-2007 or (ii) by moving five-year windows to absorb annual volatility

> In tables, data are presented for the start year (1998), the latest year (2007) and the average for the recent five years (2002-2006)

> Analytically, 2007 is compared with the recent average as an index of improvement.

Methodology: international comparisons

There are 20 geographical entities covered in this report, including Ireland. Where reference is made to the comparator group, it is to these 20 entities that the report refers.

The comparator group is spread by geography and type, and is thus of value for comparison with any national research base. It includes both major research economies, such as China, the EU and the USA, and a spread of smaller countries.

Table 2. Comparator countries in this report

Country group	Country name
	Ireland
G7	USA
	UK
Other W Europe	Belgium
	Denmark
	Finland
	Netherlands
	Portugal
	Sweden
Other E Europe	Czech Republic
Other Europe	EU27 group
Regional	Northern Ireland
	Scotland
Other World	Australia
	Brazil
	China
	India
	New Zealand
	Singapore
	South Korea

The combined output of the selected countries in the comparator group accounts for a high proportion of the world's relatively highly cited papers over the last 20 years. Highly cited papers are, in this context, those that have been identified by Thomson Reuters as the most cited 1% by field and year of publication. The comparator group covers similar proportions of total world outputs.

The combination is challenging but appropriate, including some larger and OECD countries from different continents with research bases both similar

and contrasting in structure to Ireland, and a spread of smaller nations with more comparable research activity and rapidly growing research bases with specific strengths.

A spread of leading research economies in other continents provides a broad overview of Ireland's relative international standing. Recently, the rapidly evolving research performance of China has made it central to any international research comparison. India is developing more slowly but is likely to become a key focus within a few years.

Smaller research economies are often active in specific 'niche' areas related to key technologies of economic significance. The countries of interest in a comparator group are likely to change from time to time. Those included here show rapid recent growth and a significant increase in citation impact. The smaller but dynamic economies such as South Korea, Singapore, Brazil and New Zealand demonstrate a growth rate and dynamism that would be the envy of many much larger economies. They also have other characteristics, driven by growth, that make them particularly suitable for comparison with Ireland.

The research base varies in structure between countries (as noted above) and there are also differences – possibly but not necessarily as a consequence – in research culture and thus in activities such as publication and citation behaviour.

Two regional comparators are included because of geographical proximity: Northern Ireland is a region rather than an economy in itself, as is Scotland. There are important differences between regions and whole countries which need to be borne in mind in detailed comparisons. For example, this work requires analysis of the Republic of Ireland (an OECD country) and Northern Ireland (a UK region that does not exist in OECD data). A region has complex interactions with other regions within its nation and is not an independent economic entity. Its research activity does not represent a balanced system, so it may for example have much greater outputs than would be predicted by its local economy because of input funding from other regions.

Overall, in tables, there is a description of background change for the world benchmark, for the average across the comparator group and for Ireland as a whole. Graphically, data are presented with Ireland and a sub-set of comparator countries as benchmarks. All citation data are normalised as 'citation impact' against the world baseline.

Methodology: discipline

The intention of the project was to explore the subject-based distribution of research performance through a disaggregation of the national research base according to the OECD's system of Fields of Science (FoS). The OECD system makes use of six major fields and 42 minor fields nested hierarchically.

An advantage to using the OECD system is that a wide range of other, international data on funding, workforce and training can then be readily linked through the same categories. The disadvantage is that the OECD system is constructed primarily to serve an economic purpose. The structure of knowledge exploitation - to create new products and processes - is necessarily cross-disciplinary. It therefore maps only partially to the structure of knowledge innovation in public-sector research. Some customisation is therefore required to use the OECD system in a sensible way.

For example, the OECD major category "Natural Sciences" subsumes biological, environmental and physical sciences. Within the research base these are clear and separate categories, but not within the economy. For a research overview it would make little sense to report on 'natural sciences' as a single category, however, because it accounts for such a large slice of public funds. By contrast, the OECD major category for Agricultural Science represents an area of significant economic activity but a relatively marginal part of most countries' research strategy.

To overcome this problem, it was decided that high-level reporting should be pitched at the level of categories broadly corresponding to distinct 'faculties' within a research-focused university. There are ten such categories, rather than the six of the OECD, because of the sub-division within natural sciences.

Within the OECD minor categories, several categories refer to 'biotechnology' in its different industrial sector guises. This has no correspondence with the underlying research which is generic and pre-sectoral. It is therefore necessary to amalgamate these in a research analysis. By contrast, there is but a single category for biological sciences

whereas the research base contains an evident division between broadly molecular and broadly organismal biology. It is therefore desirable to use a sub-categorisation in this area to achieve a sensible aggregation for reporting.

After reviewing the structure of the OECD system, the OECD minor categories were aggregated into some twenty categories (referred to as "project" research areas) more relevant to the research-base, albeit of somewhat variable scope.

Category naming is then an additional problem. The twenty "project" categories are created for this project. They do not nest hierarchically into the ten main *Evidence* research areas. The underlying bibliometric data are mapped directly onto the "project" areas. As a consequence, some areas at these two levels of granularity have the same (or a very similar) label but actually subsume slightly different, albeit related, parts of the database. For this reason there may be apparent 'differences' between the data in, for example, Indicators 1.02 and 1.03 or between Indicators 2.02 and 2.03. These are different because they actually do draw on different article records. An alternative would have been to create a range of more distinctive category labels but it was felt that this might have confused as much as guided. The key is to read the ten main research areas as a series and the twenty "project" areas as a complementary series which reveal different aspects of the research base.

Note that detailed analyses in the social sciences and humanities are a particular challenge because these are areas where bibliometrics are of least value. Many outputs are not in journals, citation rates are low and field definitions are disputed. This is therefore an area requiring careful data management.

The system used in this report is shown in Table 3. This provides a template which can be related on the one side to management structures within the research base and on the other to related economic data; it is a reference between several different categorical systems which might be used for aggregating research disciplines. On the one hand, we have a typical structure of Faculties and Schools followed in many universities and colleges, which represent traditional management units. This is well understood across countries and it provides a platform for linking data on people, income and training. It is subject to criticism and amendment, however, because such structures do not reflect the fields into which researchers place themselves, which tend to be finer grained, nor the increasingly connected basis on which research is conducted.

Linking the research base and the economic world are the categories created for this study, and informed by extensive discussions with Forfás and the HEA. The coding (abbreviated for convenience to 'F code') indicates the way in which the finer level of identified subjects of interest has been aggregated to subjects of analytical value. Biotechnology is, as noted above, a case in point because its meaning in the research base is more generic than its application by industry.

Table 4 shows a detailed allocation of Thomson Reuters' journal categories to "project" research areas. The journals included in the Thomson Reuters databases and information as to how they are selected are detailed here http://scientific.thomsonreuters.com/mjl/.

Table 3. Relationship between categories for aggregating research activity as encountered (a) in many Higher Education Institutions, (b) in Evidence's established system for international comparator reports, (c) as customised for use in the current report as "project" research areas and (d) as designated by the Frascati system in the OECD research database

Higher Education Institutions		Evidence	Forfás and the Higher Education Authority			OECD
Faculties	Schools	Main research areas	Customised "project" research area	Project code	OECD FoS code	OECD field of science
Medicine	Medicine, Clinical	1. Medical sciences	Clinical medicine	24	3.02	Clinical medicine
	Medicine, preclinical & health	2. Health & medically-related	Pre-clinical & health	23	3.01	Basic medical research
		2. Health & medically-related	Pre-clinical & health	23	3.03	Health sciences
Science	Science, Maths & statistics	5. Mathematics	Mathematics	11	1.01	Mathematics
	Science, Computer science	7. Engineering	Computer and information sciences	12	1.02	Computer and information sciences
	Science, Physics	6. Physical sciences	Material & Physical Sciences	13	1.03	Physical sciences and astronomy
		6. Physical sciences	Material & Physical Sciences	13	2.05	Materials engineering
	Science, Chemistry	6. Physical sciences	Chemical sciences	14	1.04	Chemical sciences
	Science, Earth & environment	4. Environmental sciences	Earth & Environment Science	15	1.05	Earth and related environmental sciences
		4. Environmental sciences	Earth & Environment Science	15	2.07	Environmental engineering
	Science, Biology	3. Biological sciences	Biological sciences: Organismal Biology	16	1.06	Biological sciences (excluding clinical and veterinary sciences)
		3. Biological sciences	Biological sciences: Molecular & Cellular Biology	30	1.06	Biological sciences (excluding clinical and veterinary sciences)
		3. Biological sciences	Biotechnology	22	3.04	Health biotechnology
		3. Biological sciences	Biotechnology	19	4.04	Agricultural biotechnology
	Science, Biotechnology	7. Engineering	Biotechnology	22	2.04	Chemical engineering
		1. Medical sciences	Biotechnology	22	2.06	Medical engineering
		4. Environmental sciences	Biotechnology	22	2.08	Environmental biotechnology
		7. Engineering	Biotechnology	22	2.09	Industrial biotechnology
		3. Biological sciences	Agricultural sciences	25	4.01	Agriculture, forestry, fisheries
		3.. Biological sciences	Agricultural sciences	25	4.02	Animal and dairy science
	Science, Agriculture	3. Biological sciences	Agricultural sciences	25	4.03	Veterinary science
		3. Biological sciences	Agricultural sciences	25	4.05	Other agricultural science
		7. Engineering	Agricultural biotechnology & engineering (including Food & Beverage science)	19	2.11	Other engineering and technologies
Engineering	Engineering, Nano-technology	6. Physical sciences	Nano-technology	18	2.10	Nano-technology

Higher Education Institutions		Evidence	Forfás and the Higher Education Authority			OECD	
Faculties	Schools	Main research areas	Customised "project" research area	Project code	OECD FoS code		OECD field of science
	Engineering, Civil	7. Engineering	Civil engineering	17	2.01		Civil engineering
	Engineering , Electrical & electronic	7. Engineering	Electrical engineering, electronic engineering, information engineering	20	2.02		Electrical engineering, electronic engineering, information engineering
	Engineering , Mechanical	7. Engineering	Mechanical engineering	21	2.03		Mechanical engineering
Social science & business	Social science, Psychology	2. Health & medically-related	Psychology	26	5.01		Psychology
	Social science, Business	9. Business	Economics & business	27	5.02		Economics and business
		8. Social sciences	Social sciences	28	5.03		Educational sciences
		8. Social sciences	Social sciences	28	5.04		Sociology
		8. Social sciences	Social sciences	28	5.05		Law
	Social sciences	8. Social sciences	Social sciences	28	5.06		Political science
		8. Social sciences	Social sciences	28	5.07		Social and economic geography
		8. Social sciences	Social sciences	28	5.08		Media and communication
		8. Social sciences	Social sciences	28	5.09		Other social sciences
		10. Humanities	Humanities	29	6.01		History and archaeology
		10. Humanities	Humanities	29	6.02		Languages and literature
Arts & humanities	Arts & humanities	10. Humanities	Humanities	29	6.03		Philosophy, ethics and religion
		Not analysed	Humanities	29	6.04		Art (arts, art history, performing arts)
		10. Humanities	Humanities	29	6.05		Other humanities

Table 4. Mapping between "project" research areas a variant of OECD FoS) and Thomson Reuters journal categories

Project research area	Thomson Reuters description
Other	Multidisciplinary Sciences
Clinical medicine	Allergy, Anaesthesiology, Andrology, Cardiac & Cardiovascular Systems, Clinical Neurology, Critical Care Medicine, Dentistry, Oral Surgery & Medicine, Dermatology, Emergency Medicine, Endocrinology & Metabolism, Gastroenterology & Hepatology, Geriatrics & Gerontology, Gerontology, Haematology, Integrative & Complementary Medicine, Medicine, General & Internal, Neuroimaging, Obstetrics & Gynaecology, Oncology, Ophthalmology, Orthopaedics, Otorhinolaryngology, Paediatrics, Peripheral Vascular Disease, Psychiatry, Radiology, Nuclear Medicine & Medical Imaging, Respiratory System, Rheumatology, Surgery, Transplantation, Urology & Nephrology
Pre-clinical & health	Anatomy & Morphology, Medicinal Chemistry,, Health Care Sciences & Services, Health Policy & Services, Immunology, Infectious Diseases, Medical Ethics, Medical Informatics, Medicine, Legal, Medicine, Research & Experimental, Neurosciences, Nursing, Nutrition & Dietetics, Parasitology, Pathology, Pharmacology & Pharmacy, Physiology, Psychology, Clinical, Psychology, Psychoanalysis, Public, Environmental & Occupational Health, Rehabilitation, Biomedical Social Sciences, Sport Sciences, Substance Abuse, Toxicology, Tropical Medicine
Biological sciences: Molecular & Cellular Biology	Biochemical Research Methods, Biochemistry & Molecular Biology, Biophysics, Cell Biology, Genetics & Heredity, Microbiology, Virology
Biological sciences: Organismal Biology	Biodiversity Conservation, Biology, Biology, Miscellaneous, Developmental Biology, Ecology, Entomology, Evolutionary Biology, Limnology, Marine & Freshwater Biology, Mathematical & Computational Biology, Mycology, Ornithology, Plant Sciences, Reproductive Biology, Zoology
Biotechnology	Biotechnology & Applied Microbiology, Biomedical Engineering, Chemical Engineering, Materials Science, Biomaterials, Medical Laboratory Technology, Microscopy
Agricultural biotechnology *	Agricultural Engineering (part), Biotechnology & Applied Microbiology (part), Food Science & Technology (part),
Agricultural sciences	Agricultural Engineering, Food Science & Technology, Agricultural Economics & Policy, Dairy & Animal Science, Multidisciplinary Agriculture, Agronomy, Fisheries, Forestry, Horticulture, Soil Science, Veterinary Sciences
Earth & Environment Science	Energy & Fuels, Environmental Engineering, Geological Engineering, Marine Engineering, Ocean Engineering, Petroleum Engineering, Environmental Sciences, Geochemistry & Geophysics, Physical Geography, Geology, Multidisciplinary Geosciences, Meteorology & Atmospheric Science, Mineralogy, Mining & Mineral Processing, Oceanography, Palaeontology, Remote Sensing, Water Resources
Mathematics	Pure Mathematics, Applied Mathematics, Interdisciplinary Applications in Mathematics, Mathematical Physics, Statistics & Probability
Physical & materials sciences	Acoustics, Astronomy/Astrophysics, Ceramics, Materials Characterisation & Testing, Coatings & Films, Composites, Multidisciplinary Materials Science, Paper & Wood, Textiles, Metallurgy & Metallurgical Engineering, Optics, Applied Physics, Atomic, Molecular & Chemical Physics, Condensed Matter Physics, Fluids & Plasmas, Multidisciplinary Physics, Nuclear Physics, Particles & Fields
Chemical sciences	Analytical Chemistry, Applied Chemistry, Inorganic & Nuclear Chemistry, Multidisciplinary Chemistry, Organic Chemistry, Physical Chemistry, Crystallography, Electrochemistry, Polymer Science
Nanotechnology	Nanoscience & Nanotechnology

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Project research area	Thomson Reuters description
Computer and information sciences	Artificial Intelligence, Cybernetics, Information Systems, Interdisciplinary Applications in Computer Science, Software Engineering, Computer Science Theory & Methods
Civil engineering	Construction & Building Technology, Civil Engineering, Transportation Science & Technology
Electrical engineering, electronic engineering, information engineering	Automation & Control Systems, Communication, Computer Science, Hardware & Architecture, Electrical & Electronic Engineering, Imaging Science & Photographic Technology, Instruments & Instrumentation, Robotics, Spectroscopy, Telecommunications
Mechanical engineering	Aerospace Engineering, Mechanical Engineering, Multidisciplinary Engineering, Mechanics, Nuclear Science & Technology, Thermodynamics
Economics and Business	Business, Economics, Finance, Industrial Relations & Labour, Management, Operations Research & Management Science
Social sciences	Anthropology, Area Studies, Asian Studies, Criminology & Penology, Demography, Education & Educational Research, Education – Scientific Disciplines, Special Education, Environmental Studies, Ethnic Studies, Family Studies, Geography, Information Science & Library Science, International Relations, Law, Planning & Development, Political Science, Public Administration, Social Issues, Interdisciplinary Social Sciences, Mathematical Methods in Social Sciences, Social Work, Sociology, Transportation, Urban Studies, Women's Studies
Psychology	Behavioural Sciences, Ergonomics, Psychology, Applied Psychology, Biological Psychology, Developmental Psychology, Educational Psychology, Experimental Psychology, Mathematical Psychology, Multidisciplinary Psychology, Social Psychology
Humanities	Archaeology, Architecture, Art, Classics, Dance, Ethics, Film, Radio & Television, Folklore, History, History & Philosophy of Science, History of Social Sciences, Multidisciplinary Humanities, Language & Linguistics, Literary Reviews, Literary Theory & Criticism, Literature, Literature of specific areas (African, Australian & Canadian; American; British Isles; German, Dutch & Scandinavian; Romance; Slavic), Medieval & Renaissance Studies, Music, Philosophy, Poetry, Religion, Theatre

* Agricultural biotechnology As the text elsewhere explains, while individual projects may be recognised as 'agricultural biotechnology' and there may be a distinctive investment and economic description, the research base does not recognise a significant volume of biotechnology research which is addressed solely at the agricultural sector. The distinctions between biotechnology for agriculture, environment, health and/or industry which are made by OECD for economic purposes do not sit easily with a discipline based structure for universities and research institutes. A compromise structure has been created here for this report so that some preliminary and indicative outcomes are available, but this is likely to be a satisfactory analysis only within the broad overview of this project. A more detailed and comprehensive analysis at journal level would be desirable if resources were available. If supported by advice from relevant sectoral specialists, this might then lead to a more detailed and targeted deconstruction of the links between the academic, applied and industrial elements of the 'agricultural biotechnology' theme..

The objectives of the study

The overall objective described by Forfás and the HEA for this study is to profile research activity and areas of emerging and existing research strengths across the public research base.

The study focuses on a ten-year period (1998-2007) and the research disciplines have been mapped with reference to discipline categories linked to the OECD Fields of Science (FoS) Classification.

The analyses and the report are based solely on publication and citation data, generally referred to as bibliometrics.

The outputs described here are:

- A profile of research activity for the island of Ireland, while separately identifying the results for Ireland and Northern Ireland
    - Benchmarks of Ireland's research profile against suitable comparator countries
    - Measures of the quantity of the research undertaken
    - Measures of the quality of research, via bibliometrics
    - Trends in research activity over the period 1998-2007
- Measures of the quantity and nature of research by HEI
- An assessment of the level of research collaboration through co-publication.

This is a complex and wide-ranging specification encompassing several wholly different, conceptual approaches.

Section 1 is an evaluation of the International Comparative Research Performance of Ireland, using field definitions linked to the OECD structure but not relying solely on that.

Comparator countries need to be seen as working models rather than strictly defensible statements of relative international performance. Each country differs in population, GDP (total economy), GERD (research expenditure), the structure of its research base and its history of research and development. In any reporting structure, the preferred set of comparators is likely to change through successive iterations in response to policy objectives and when anomalies, and their explanation, emerge.

Section 2 is a disaggregation of Institutional Comparative Research activity. The structure of this work was informed in part by the outcomes of Phase 1: there is sufficient activity in some subject areas to justify a relatively fine-grained approach whereas in other areas no such disaggregation would be appropriate because the activity by institution would be too small to provide meaningful statistics.

Section 3 analyses Research Collaboration, a key policy issue. Collaboration underpins an increasing share of global research because it is an important enabler of cutting-edge innovation, by concentrating resources and linking intellectual capital. International research collaboration is driven by a consonance between top-down and bottom-up objectives.

- Collaboration is encouraged at a policy level because it provides access to a wider range of facilities and resources. It enables researchers to participate in networks of cutting-edge and innovative activity.
- For researchers, collaboration provides opportunities to move further and faster by working with other leading people in their field. It is therefore unsurprising that collaborative research is also identified as contributing to some of the highest citation impact activity.
- Collaboration within countries is equally important, and for similar reasons. It provides both intellectual links and access to facilities. It is likely to enable faster innovation.

This report provides a reference benchmark and a resource for further work. It is intended to provide information for policy work and to create a basis for discussion. The use of bibliometric data to study international collaboration is relatively new, and caution is needed in interpreting the data. This is particularly the case with China and Brazil because of their rapid growth and the time-lags involved between research initiation, publication of outcomes and international recognition. Such considerations should also apply to other expanding research economies, such as that of Ireland.

It is also important to recognise that collaboration may serve purposes in addition to research excellence, such as gaining knowledge of other

research systems and building strategic partnerships. The narrative and conclusions are therefore provisional because the situation is in fact complex and dynamic. Each country has its own portfolio, policies and priorities. The present outcome is a transitional and rapidly changing interface between these. These dynamics present opportunities but also carry threats for countries less well positioned to participate.

A further policy issue we sought to explore was that of emerging fields. This analysis was frustrated by the relatively small absolute volume of Irish output compared to world. While it is quite clear that Ireland does contribute to a number of key research fronts, the actual volume involved is so small when global filters are applied (to keep the data manageable) that the outcome provides neither a clear direction nor a clear identification of the main contributors.

Section 4 provides Impact Profiles® to examine the statistical distribution of Irish research performance. This is important because a general property of research activity is that it is skewed. Measures such as 'average' may therefore give only partial information about the underlying spread of excellence where a more detailed profile reveals additional and important facts about how much of total activity is in fact of international standing.

The balance of activity between the percentage above and below world average and the smaller percentage that is relatively highly cited (more than 4 times world average for year and discipline) throws light on the extent to which the national average outcome (the indicator most widely reported) may be dependent on a small part of national activity.

Structure of the report

The analyses are reported in the three sections indicated earlier.

In Sections 1 and 2 the data are analysed in two ways. First, in terms of quantity via an analysis of volume output (numbers of papers in Thomson Reuters' indexed journals). Second, in terms of quality via an analysis of citation impact (citations per paper rebased to relevant world averages for year and field).

Indicator 1.04 analyses the total citation counts to papers from Ireland and comparator countries. Similar analyses for each category were presented to an early meeting of the project team group for this report. That group agreed that citation counts did not significantly augment the information provided by, on the one hand, publication counts and, on the other hand, citation impact analyses (citations per paper). The summary indicator is retained for reference.

Section 1 refers to international comparative analyses for Ireland as a whole. There are a series of analyses at the level of ten major 'faculty' categories and these are then disaggregated across 20 "project" research areas created from the OECD minor Fields of Study by grouping activity at a level relevant to the research base (Table 3).

Ireland is characterised by an exceptional growth rate compared to most EU countries; this is shown in Figure 1 (see Thematic Summary). This has a particular effect on its indexed research impact (here = citation impact) because many current papers cite relatively few past papers while there are fewer international links to recognise current activity. For Ireland, as for China and other countries in a similar position of growth, this has the consequence of producing a dip in indexed citation impact on the most recent year or two years of any time series.

Section 2 refers to HEI research within Ireland and Northern Ireland. An initial series of analyses at the major 'faculty' level is then followed by a series of specific analyses but only in select categories among the 20 "project" research areas, where there is sufficient volume to justify disaggregation. These disaggregations are of: biological sciences (into organismal and molecular sections), physical sciences (into physics & materials and chemistry sections) and engineering (into civil, electrical and mechanical sections).

In the second part of section 2 the citation impact analysis is applied only to those institutions which have sufficient volume to support such an analysis. Small volumes of activity are likely neither to provide a good guide nor to refer to any significant capacity which would drive the overall profile, and therefore several institutions are omitted.

Because of the small volume of activity for the smaller colleges, their research output has been amalgamated into a single line.

Section 3 considers research collaboration as reflected in co-authorship. Analyses look at international collaboration and at collaboration between institutions within Ireland and Northern Ireland. Commentary is attached to each table.

Section 4 presents Impact Profiles® for the total Ireland research base and then for six research areas selected by Forfás and the HEA. Commentary is attached to each analysis.

Indicator summary pages

The body of this report is a page by page summary of the detailed quantitative analyses for each indicator. Each page follows a similar pattern.

o Table of key results (actual values and ranked performance among comparators) for the latest year for which data are available and the average value for the previous five years. The Table shows performance relative to comparator group average and ranked performance against the comparator group. Also shown is the Ireland share of group (sometimes world); for 'relative' indicators (where one measure is expressed relative to another).

o Charts of data for Ireland and key comparators (or for larger institutions) showing trends.

o Description of and commentary on the indicator.

In Section 2, for some institutions, the output data for a particular project research area may be too sparse (a) to provide a sufficient basis for an informative 'change' index or (b) to provide a reliable citation impact index. In such cases the relevant cells are left blank.

1.01   Number and share of world papers

Table 1.01 Number of papers

Indicator identification and description

Chart 1.01 Share of world papers

Key results for Ireland actual and ranked performance in latest data year and average for previous five years

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland papers	2,569	3,513	4,657	+33%
Group average papers	25,263	30,625	35,017	+14%
Ireland / Group average	0.10	0.11	0.13	+16%
Ireland rank within Group	16	18	18	⇔
Ireland as share of charted nations (%)	3.03	3.54	4.20	⇧
Ireland share of world (%)	0.35	0.42	0.50	+20%

Change in performance ranked among total comparator group

Change (ratio or difference) between last year and recent

Chart illustrating performance trend of comparators over last decade

Charts may omit comparators if inclusion would distort vertical axis

Data & analysis: Evidence, Thomson Reuters

Data & analysis: Evidence, Thomson Reuters

Commentary

Ireland shows an impressive increase (33%) in terms of research output, measured as the number of publications indexed by Thomson Reuters across all disciplines. This rate of increase far exceeds the average for the comparator group, and is second only in growth to China (59%). Ireland's ranking at 18th in the group is unchanged (ahead only of Northern Ireland), but growth rates compare very favourably with Scotland (9%) and Northern Ireland (13%). If these trends continue then Ireland could expect to overtake New Zealand in terms of volume of published research within the next few years.

Ireland's share of world papers is small seen against this comparator group of nations, all of which have larger populations, higher GDP (total economy) and greater GERD (Gross Domestic Expenditure on Research and Development). Irish research outputs have however become consistently more frequent over the last ten years. Scandinavian comparators are, at best, maintaiinng a level output rate, although Sweden has seen a significant reduction in output over the last decade. Both Belgium and Australia do show consistent growth, but their's is not as great as that for Ireland.

Text may include commentary on additional issues arising from data or indicators

1.01   Number and share of world papers

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	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland papers	2,569	3,513	4,657	+33%
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Data & analysis: Evidence, Thomson Reuters

Chart 1.01 Share of world papers

Data & analysis: Evidence, Thomson Reuters

Commentary

Ireland shows an impressive increase (33%) in terms of research output, measured as the number of publications indexed by Thomson Reuters across all disciplines. This rate of increase far exceeds the average for the comparator group, and is second only in growth to China (59%). Ireland's ranking at 18th in the group is unchanged (ahead only of Northern Ireland), but growth rates compare very favourably with Scotland (9%) and Northern Ireland (13%). If these trends continue then Ireland could expect to overtake New Zealand in terms of volume of published research within the next few years.

Ireland's share of world papers is small seen against this comparator group of nations, all of which have larger populations, higher GDP (total economy) and greater GERD (Gross Domestic Expenditure on Research and Development). Irish research outputs have however become consistently more frequent over the last ten years. Scandinavian comparators are, at best, maintaining a level output rate, although Sweden has seen a significant reduction in output over the last decade. Both Belgium and Australia do show consistent growth, but theirs is not as great as that for Ireland.

1.02.01 Number and share of world papers in 10 main research areas

Table 1.02.01 Number of clinical papers

|	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland papers	1,309	1,689	2,194	+30%
Group average papers	12,848	14,644	16,290	+11%
Ireland / Group average	0.10	0.12	0.13	+17%
Ireland rank within Group	15	15	15	⇔
Ireland as share of charted nations (%)	2.75	2.97	3.55	⇧
Ireland share of world (%)	0.38	0.45	0.55	+21%

Data & analysis: Evidence, Thomson Reuters

Chart 1.02.01 Share of world clinical papers
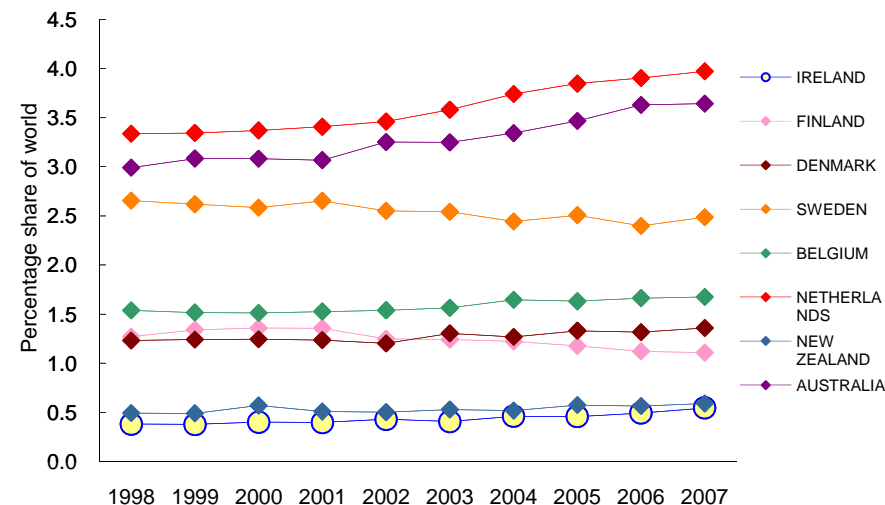
Data & analysis: Evidence, Thomson Reuters

Commentary

The rate at which clinical research outputs from Ireland are increasing (30%) is only exceeded (within the comparator group) by China, South Korea, India, the Czech Republic and Brazil. This is an impressive increase in comparison with increases in Northern Ireland (12%), Scotland (5%) and the UK as a whole (8%). Ireland's ranking within the group, in terms of volume of published clinical research, remains unchanged at 15th.

The chart shows that Ireland's share of world papers is small set against these comparator nations, but highlights good growth against this low baseline, especially in the period 2003-2007. Clinical research outputs from the Netherlands and Australia also show strong growth, with moderate growth in Belgium. Research volume expressed as the percentage of world total from other comparator nations is at a steady level, or declining (Sweden, Finland).

Table 1.02.02 Number of health & medically-related papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland papers	127	143	180	+26%
Group average papers	1,518	1,597	1,747	+9%
Ireland / Group average	0.08	0.09	0.10	+15%
Ireland rank within Group	16	18	17	⇧
Ireland as share of charted nations (%)	2.04	2.29	2.74	⇧
Ireland share of world (%)	0.32	0.35	0.42	+19%

Data & analysis: Evidence, Thomson Reuters

Chart 1.02.02 Share of world health & medically-related papers
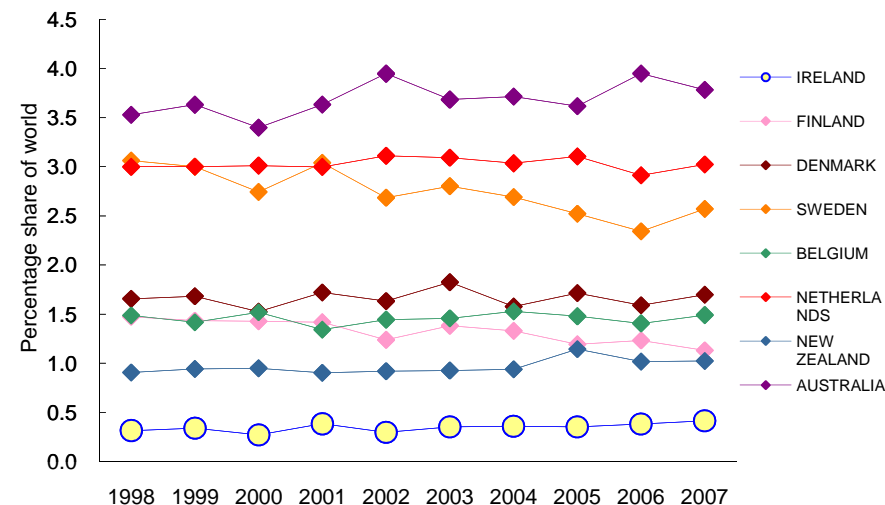
Data & analysis: Evidence, Thomson Reuters

Commentary

Over the last five years, in terms of the volume of health and medically-related publications, Ireland has moved one place up the rankings within the group (from 18th to 17th position) by overtaking Singapore. The growth of Irish research (26%) is impressive, exceeded only by China (74%), South Korea (32%) and the Czech Republic (38%). The Czech Republic is an interesting comparator nation, as the volume of research here is similar to that produced by Ireland. The volume of UK research in this discipline showed a 5% reduction in 2007 compared with the average volume for the previous five years.

Ireland's share of world papers in health and medically-related papers is very small set against these comparator nations. The nearest comparators (New Zealand, Finland, Belgium and Denmark) produce up to four times as many papers as Ireland. Ireland does however show a consistent and steady growth in terms of the percentage share of total world outputs.

Table 1.02.03 Number of biological sciences papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland papers	707	933	1,252	+34%
Group average papers	6,019	7,102	7,845	+10%
Ireland / Group average	0.12	0.13	0.16	+21%
Ireland rank within Group	16	17	17	⇔
Ireland as share of charted nations (%)	2.98	3.30	4.31	⇧
Ireland share of world (%)	0.43	0.50	0.62	+25%

Data & analysis: Evidence, Thomson Reuters

Chart 1.02.03 Share of world biological sciences papers
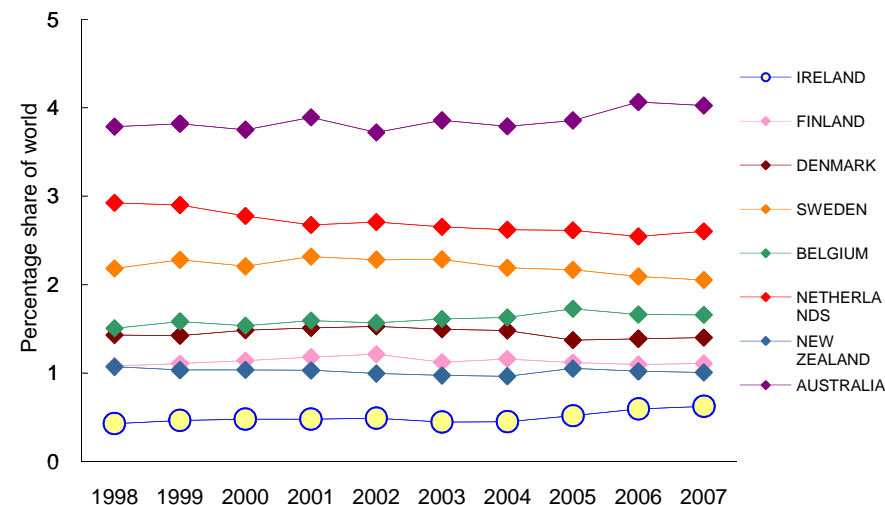
Data & analysis: Evidence, Thomson Reuters

Commentary

Ireland shows very strong growth in the number of papers published in biological sciences (34%), second only to China (81%) in our comparator group. This is an area where Ireland is particularly strong in terms of percentage of total world output (0.62%) against an average across all disciplines of 0.5%.

Ireland's share of world papers in biological sciences is small set against these comparator nations. Ireland shows strong and significant growth in this subject over the last five years (25% increase in terms of world share). Australia is the only other country to show an increase in world share over this period (4%) while other comparators show negligible increase or decrease in world share (7% decrease in the case of Sweden). Ireland's performance in biological sciences is particularly impressive given the intense international activity in this field.

1.02.04 Number and share of world papers in 10 main research areas

Table 1.02.04 Number of environment papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland papers	160	288	395	+37%
Group average papers	1,959	2,639	3,154	+20%
Ireland / Group average	0.08	0.11	0.13	+15%
Ireland rank within Group	17	17	17	⇔
Ireland as share of charted nations (%)	1.99	2.52	3.13	⇧
Ireland share of world (%)	0.32	0.43	0.51	+17%

Data & analysis: Evidence, Thomson Reuters

Chart 1.02.04 Share of world environment papers
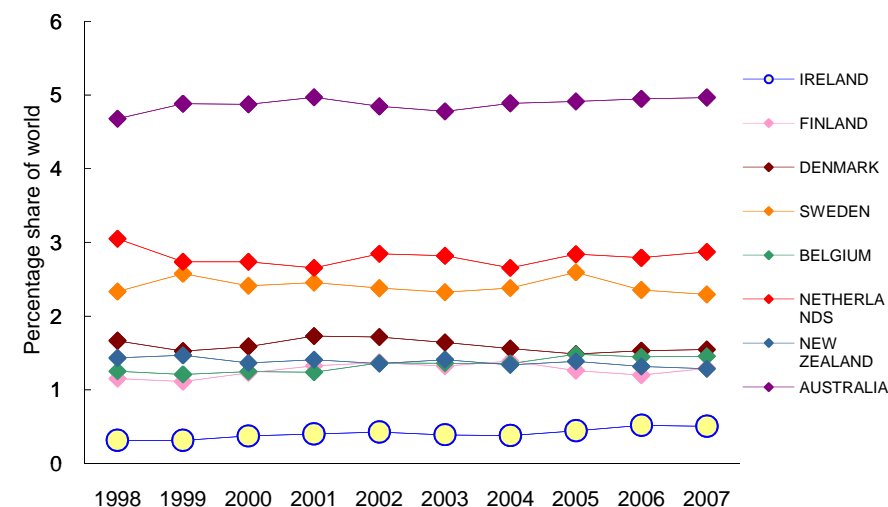
Data & analysis: Evidence, Thomson Reuters

Commentary

Ireland shows very strong growth in the number of papers published in environment (37% increase). Despite this large increase Ireland's ranking remains unchanged, ahead of Northern Ireland and Singapore, but still some way behind the Czech Republic (which has increased its volume of outputs over the last five years by 29%).

In terms of percentage share of world environment papers Ireland (0.51%) lags behind its nearest comparators – New Zealand (1.29%), Finland (1.29%), Belgium (1.45%) and Denmark (1.55%). However, Ireland's rate of output growth (37%) is more than double that of Finland (17%), with the other three countries growing at rates from 11-14%. Even so, given this baseline and assuming current trajectories continue, it would be some time before Irish outputs reached the levels of these four nations.

Table 1.02.05 Number of mathematics papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland papers	101	142	168	+18%
Group average papers	975	1,201	1,396	+16%
Ireland / Group average	0.10	0.12	0.12	+2%
Ireland rank within Group	18	17	17	⇔
Ireland as share of charted nations (%)	4.16	4.61	5.37	⇧
Ireland share of world (%)	0.35	0.41	0.42	+4%

Data & analysis: Evidence, Thomson Reuters

Chart 1.02.05 Share of world mathematics papers
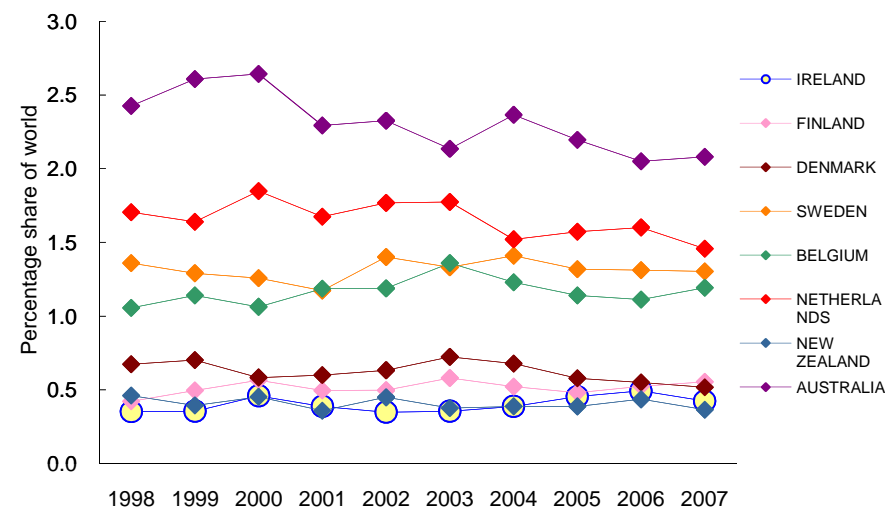
Data & analysis: Evidence, Thomson Reuters

Commentary

The number of mathematics papers produced in Ireland has increased by 18% in 2007 compared with the average of the previous five years. This is the smallest increase for any of the main research areas covered in this study and is only 2% better than the average for the comparator group. Ireland's share of world total output is only 0.42, which is low in comparison with the other main research areas.

In the context of these comparator countries Ireland's mathematics output appears satisfactory, with only Finland (7% growth in world share) showing an increase greater than Ireland (4% growth in world share). All the other countries in the chart have seen a decline in world share in 2007 compared with the previous five years. Two other comparable countries however have achieved a greater increase in share of world output (Scotland 8%; Czech Republic 18%).

Table 1.02.06 Number of physical sciences papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland papers	680	1,055	1,334	+26%
Group average papers	7,180	9,493	11,021	+16%
Ireland / Group average	0.09	0.11	0.12	+9%
Ireland rank within Group	18	17	17	⇔
Ireland as share of charted nations (%)	3.15	3.90	5.15	⇧
Ireland share of world (%)	0.28	0.37	0.42	+15%

Data & analysis: Evidence, Thomson Reuters

Chart 1.02.06 Share of world physical sciences papers
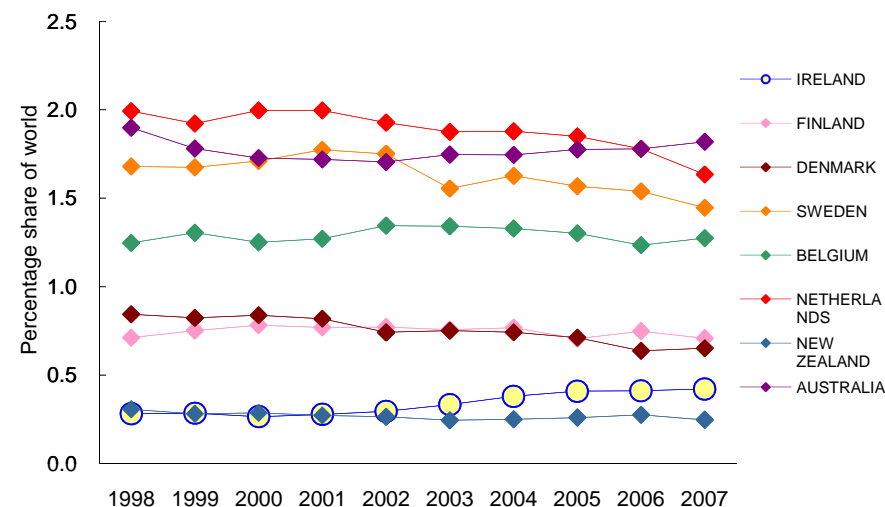
Data & analysis: Evidence, Thomson Reuters

Commentary

Ireland shows strong growth in the number of papers published in physical sciences (26%) which is 9% greater than the average for comparator countries. Ireland's share of the world total outputs was only 0.28% in 2001, but by 2007 this had increased to 0.42%. This is still low in comparison with Ireland's performance in the other main research areas but the rate of growth is very strong, exceeded only by China and India. More than half the countries in the comparator group suffered a net loss in world share during the same period.

The chart shows that Ireland's share of physical science papers has increased strongly and consistently since 2001 – an increase of 15%. Australia has achieved an increase in share of world output of 4% over the same period, while all the other charted nations have seen their share fall. This is the case also for Northern Ireland, Scotland and the UK as a whole. New Zealand's performance was comparable with Ireland's ten years ago, but its trajectory has been downward. Given that successful physical science research is often dependant on substantial and well-established facilities these trends are likely to continue.

1.02.07 Number and share of world papers in 10 main research areas

Table 1.02.07 Number of engineering papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland papers	543	850	1,244	+46%
Group average papers	5,728	7,282	8,973	+23%
Ireland / Group average	0.09	0.12	0.14	+19%
Ireland rank within Group	18	17	17	⇔
Ireland as share of charted nations (%)	3.38	4.11	5.63	⇧
Ireland share of world (%)	0.30	0.39	0.49	+25%

Data & analysis: Evidence, Thomson Reuters

Chart 1.02.07 Share of world engineering papers
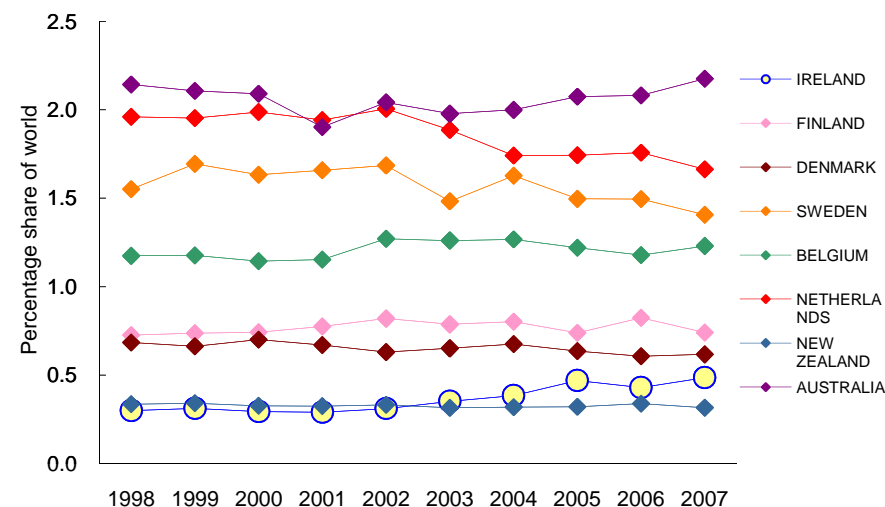
Data & analysis: Evidence, Thomson Reuters

Commentary

Ireland shows very strong growth in the number of papers published in engineering (46%), second only to China (69%) in the comparator group. Ireland's share of world outputs has risen dramatically from 0.30% in 1998 to 0.49% in 2007. Despite this Ireland remains at 17th position in terms of ranking within the group, ahead of New Zealand and Northern Ireland. If trajectories continue as at present, Irish outputs could be expected to exceed those of Denmark, Scotland and Finland within the next 5-10 years.

The chart shows that Ireland's share of engineering papers has increased strongly and consistently since 2001 – an increase of 25%. Australia has achieved an increase in percentage share of world output of 7% over the same period, while all the other nations represented on the chart have seen their percentage share fall. In 1998 engineering in Ireland was weak in comparison with Irish outputs in other research areas; by 2007 it had moved up to the middle of the league.

Table 1.02.08 Number of social science papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland papers	67	131	244	+86%
Group average papers	1,149	1,398	1,651	+18%
Ireland / Group average	0.06	0.09	0.15	+57%
Ireland rank within Group	16	15	15	⇔
Ireland as share of charted nations (%)	2.21	2.90	4.49	⇧
Ireland share of world (%)	0.27	0.42	0.68	+61%

Data & analysis: Evidence, Thomson Reuters

Chart 1.02.08 Share of world social science papers
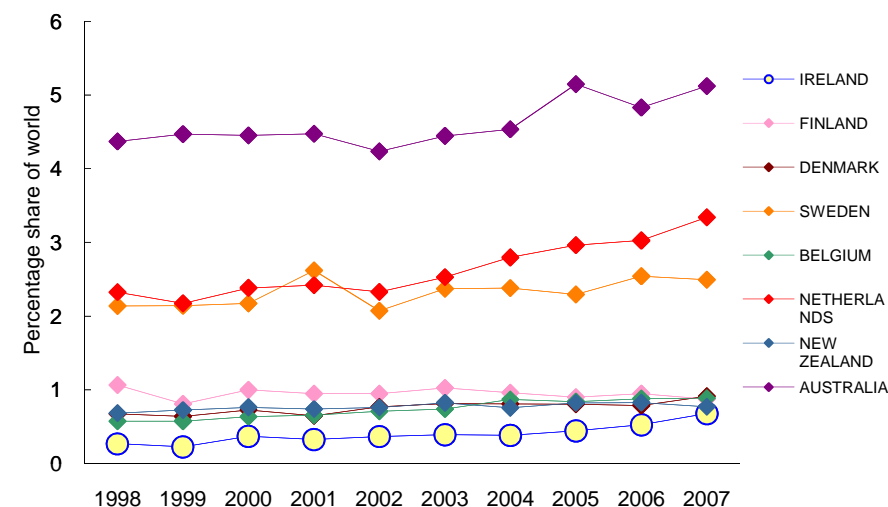
Data & analysis: Evidence, Thomson Reuters

Commentary

There has been substantial growth in the number of Irish authored social science papers over the last ten years. From a very low base in 1998 (only 67 papers, or 0.27% of total world output) Ireland produced 244 papers, or 0.7% of world output, in 2007. Within Ireland, social science output has gone from being the lowest of the main research areas to the strongest in terms of volume growth. Share of the total world output has increased by 61%, which is greater even than India (56%) Brazil (36%) or China (26%), albeit less than the Czech Republic (almost doubling world share). These changes should be seen in the light of publishing patterns within social sciences, where much valuable research is published in reports rather than journals, but where research culture is also rapidly evolving.

Ireland's share of world papers in social sciences started at a very low base ten years ago set against these comparator nations. Ireland's increasing share of world total is striking, even in comparison with other countries which are also increasing their share (Australia and the Netherlands) Other charted countries have been fairly constant in output share: Finland, Belgium and New Zealand. If current trajectories continue then Ireland's world share will exceed that of these three countries within the next few years.

Table 1.02.09 Number of business papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland papers	67	71	123	+73%
Group average papers	652	762	913	+20%
Ireland / Group average	0.10	0.09	0.13	+45%
Ireland rank within Group	15	18	17	⇧
Ireland as share of charted nations (%)	3.60	3.04	4.19	⇧
Ireland share of world (%)	0.47	0.42	0.60	+44%

Data & analysis: Evidence, Thomson Reuters

Chart 1.02.09 Share of world business papers

Data & analysis: Evidence, Thomson Reuters

Commentary

Ireland shows strong growth (73% increase in 2007 compared with the average 2002-06) in terms of business research publications. This headline figure needs to be interpreted carefully however, in the context of firstly a very low baseline (67 papers in 1998; 71 average 2002-06), and secondly a possibly aberrant figure for 2007.   Irish inputs as a share of the world total also appears to have increased dramatically (by 44%). In terms of ranking within the comparator group Ireland has moved up to 17th position, moving ahead of the Czech Republic. If the 2007 figure turns out to be unusual this change of position is likely to be reversed.

The chart shows that Ireland's share of world business papers is small set against these comparator nations. Were it not for the high number of papers published in 2007 Ireland's share of world outputs overall would be fairly constant over the ten year period.

1.02.10 Number and share of world papers in 10 main research areas

Table 1.02.10 Number of humanities papers

Chart 1.02.10 Share of world humanities papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland papers	34	36	48	+33%
Group average papers	340	357	369	+3%
Ireland / Group average	0.10	0.10	0.13	+29%
Ireland rank within Group	12	11	10	⇧
Ireland as share of charted nations (%)	4.66	3.73	5.00	⇧
Ireland share of world (%)	0.37	0.38	0.50	+31%

Data & analysis: Evidence, Thomson Reuters
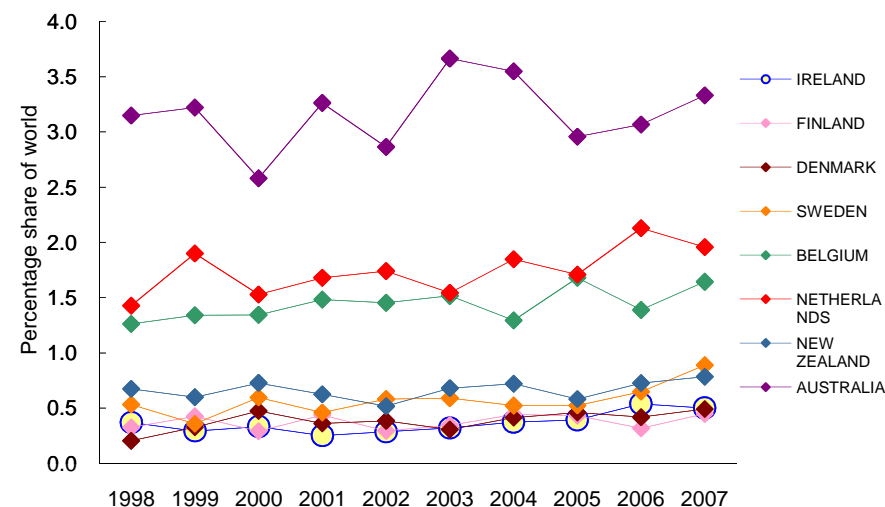
Data & analysis: Evidence, Thomson Reuters

Commentary

Ireland appears to be performing well in terms of volume of humanities papers, but the total number of papers published (34 in 1998; 48 in 2007) is very low and so trends must be interpreted with care. Ireland's high ranking within the comparator group must be seen in the light of countries with relatively large research capacity (e.g. India, Brazil) which publish virtually no humanities research. Even Chinese authors only published 53 papers in 2007. 83% of the humanities papers published worldwide in 2007 were by authors based either in the USA or the European Union.

Ireland's share of the world's humanities papers was 0.38% over the five year period 2002-06, and shows a gradual rise to 0.50% by 2007. Partly no doubt as a result of the low number of papers in total, the chart shows a lot of 'noise' in terms of percentage share of world output for all the charted countries.

Table 1.03.01 Number of clinical medicine papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland papers	740	1,007	1,309	+30%
Group average papers	6,897	8,187	9,404	+15%
Ireland / Group average	0.11	0.12	0.14	+13%
Ireland rank within Group	15	14	14	⇔
Ireland as share of charted nations (%)	2.86	3.16	3.68	⇧
Ireland share of world (%)	0.37	0.44	0.52	+18%

Data & analysis: Evidence, Thomson Reuters

Chart 1.03.01 Share of world clinical medicine papers
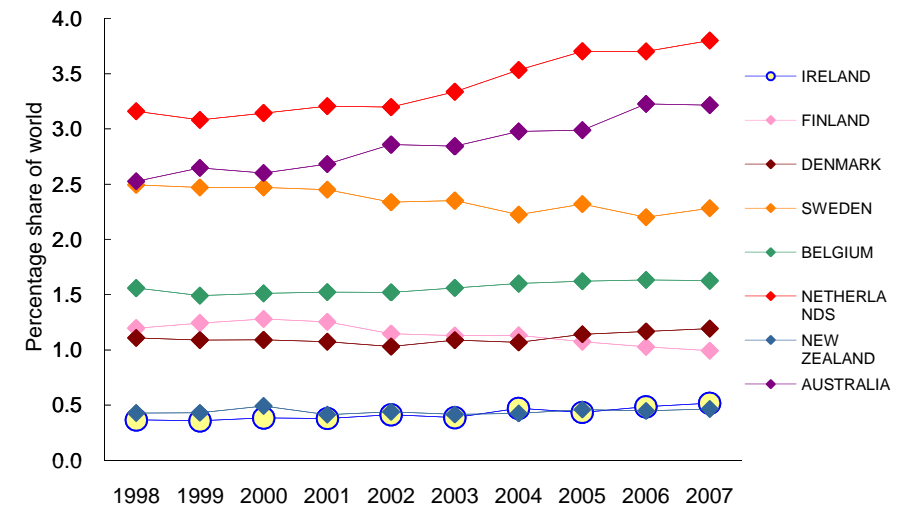
Data & analysis: Evidence, Thomson Reuters

Commentary

The rate at which clinical medicine outputs from Ireland are increasing (30%) is only exceeded (from our comparator group) by China, South Korea, India, the Czech Republic and Brazil. This is an impressive increase in comparison with increases in Northern Ireland (8%), Scotland (5%) and the UK as a whole (10%). Ireland's ranking within the group, in terms of volume of published clinical research, has moved up one position since 1998, having overtaken New Zealand.

The chart shows that Ireland's share of world papers is small set against these comparator nations, but highlights good growth against this low baseline, especially in the period 2003-2007. Clinical research outputs from the Netherlands and Australia also show strong growth, with moderate growth in Belgium. Research volume expressed as the percentage of world total from other comparator nations is at a steady level, or declining (Sweden, Finland, New Zealand).

Table 1.03.02 Number of pre-clinical & health papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland papers	395	639	887	+39%
Group average papers	5,601	6,566	7,645	+16%
Ireland / Group average	0.07	0.10	0.12	+19%
Ireland rank within Group	16	17	16	⇧
Ireland as share of charted nations (%)	2.05	2.80	3.40	⇧
Ireland share of world (%)	0.27	0.38	0.47	+24%

Data & analysis: Evidence, Thomson Reuters

Chart 1.03.02 Share of world pre-clinical & health papers
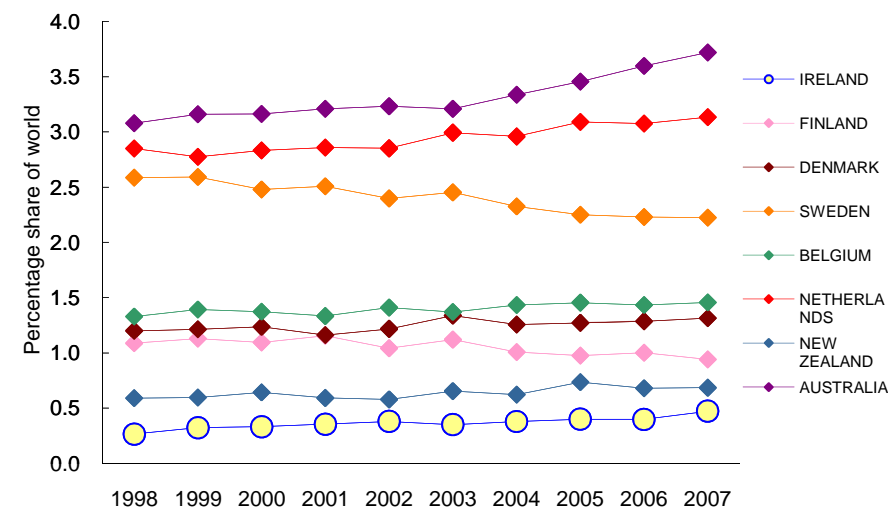
Data & analysis: Evidence, Thomson Reuters

Commentary

Over the last five years, in terms of the volume of pre-clinical and health publications, Ireland has moved one place up the rankings within the group (from 17th to 16th position) by overtaking Portugal. The growth of Irish research (39%) is impressive, exceeded only by China (79%), and matched by the Czech Republic (also 39%). The Czech Republic is an interesting comparator nation, as the volume of research here is similar to that produced by Ireland.

Ireland's share of world papers in pre-clinical and health-related papers is small set against these comparator nations. While the nearest comparator nations in terms of world share (New Zealand, Finland, Belgium and Denmark) are maintaining their percentage position, Ireland shows a consistent and steady growth in terms of the percentage share of total world outputs.

Table 1.03.03 Number of biological sciences: Organismal Biology papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland papers	505	776	1,108	+43%
Group average papers	6,339	7,658	8,575	+12%
Ireland / Group average	0.08	0.10	0.13	+27%
Ireland rank within Group	17	18	18	⇔
Ireland as share of charted nations (%)	2.15	2.67	3.70	⇧
Ireland share of world (%)	0.30	0.40	0.53	+32%

Data & analysis: Evidence, Thomson Reuters

Chart 1.03.03 Share of world biological sciences: Organismal Biology papers
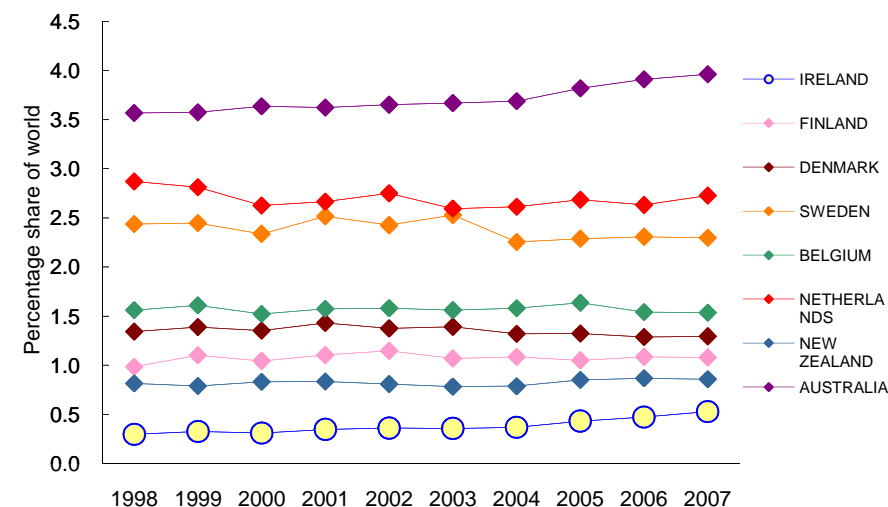
Data & analysis: Evidence, Thomson Reuters

Commentary

Ireland shows very strong growth in the number of papers published in organismal biology (43%), second only to China (65%) in the comparator group. Despite this, Ireland's ranking within the group remains 18th as the nearest competitor nations (Singapore and Portugal) also have high rates of increase. Ireland's performance in organismal biology is stronger than its overall performance in biological sciences, so this is a relatively strong area within that broader subject.

Ireland's share of world papers in organismal biology is small set against these comparator nations. Ireland shows strong and significant growth in this subject over the last five years (32% increase in terms of world share). Australia, New Zealand and the Netherlands show modest increases in world share over the same period (3-6%) while other comparators show a decrease in world share. Ireland's performance in organismal biology is impressive.

Table 1.03.04 Number of biological sciences: Molecular & Cellular Biology papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland papers	361	513	724	+41%
Group average papers	4,140	4,860	5,307	+9%
Ireland / Group average	0.09	0.11	0.14	+29%
Ireland rank within Group	16	18	17	⇧
Ireland as share of charted nations (%)	2.59	3.04	4.39	⇧
Ireland share of world (%)	0.32	0.41	0.56	+35%

Data & analysis: Evidence, Thomson Reuters

Chart 1.03.04 Share of world biological sciences: Molecular & Cellular Biology papers
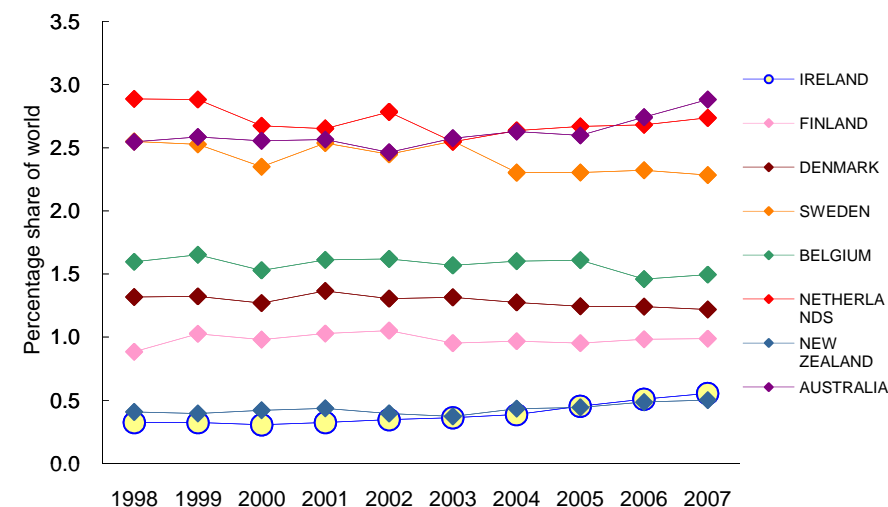
Data & analysis: Evidence, Thomson Reuters

Commentary

Ireland shows very strong growth in the number of papers published in molecular and cellular biology (41%), second only to China (65%) and Singapore (44%) in our comparator group. Ireland has improved its ranking within the group by one position (to 17th) having overtaken New Zealand. Ireland's performance in molecular and cellular biology is stronger than Irish performance in biological sciences generally. This indicates that core molecular biology, like core organismal biology, is stronger than the wider range of activity in this broad subject area.

Ireland's share of world papers in molecular and cellular biology is small set against these comparator nations. Ireland shows strong and significant growth in this subject over the last five years (35% increase in terms of world share). Australia, New Zealand and the Netherlands show modest increases in world share over the same period (3-6%) while other comparators show a decrease in world share. Ireland's growth in molecular and cellular biology is particularly impressive given the intense activity in this field on the international stage.

Table 1.03.05 Number of biotechnology papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland papers	106	207	291	+41%
Group average papers	1,038	1,374	1,640	+19%
Ireland / Group average	0.10	0.15	0.18	+18%
Ireland rank within Group	18	17	17	⇔
Ireland as share of charted nations (%)	2.84	4.29	5.89	⇧
Ireland share of world (%)	0.33	0.51	0.62	+23%

Data & analysis: Evidence, Thomson Reuters

Chart 1.03.05 Share of world biotechnology papers
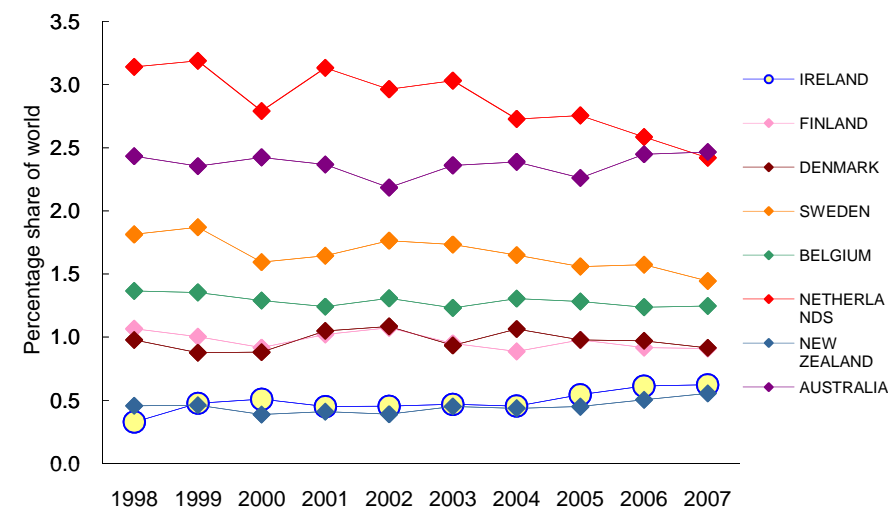
Data & analysis: Evidence, Thomson Reuters

Commentary

Ireland shows very strong growth in the number of papers published in biotechnology (41%), third only to China (77%) and New Zealand (43%) in the comparator group. Ireland's share of world outputs has almost doubled, from 0.33% in 1998 to 0.62% in 2007. Despite this Ireland remains at 17th position in terms of ranking within the group, ahead of New Zealand and Northern Ireland. If trajectories continue as at present, Irish outputs might be expected to exceed those of Czech Republic and Scotland within the next 5-10 years.

The chart shows that Ireland's share has retained or slightly increased world share of biotechnology papers over the last ten years while most comparator nations – especially Netherlands and Sweden – have seen a decrease in their world share. Biotechnology is one of Ireland's strongest subjects in terms of percentage share of total world output.

Table 1.03.06 Number of agricultural biotechnology and engineering (including food) papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland papers	136	177	200	+13%
Group average papers	275	361	442	+22%
Ireland / Group average	0.49	0.49	0.45	-8%
Ireland rank within Group	9	11	12	⇩
Ireland as share of charted nations (%)	9.87	10.69	10.88	⇧
Ireland share of world (%)	1.41	1.46	1.39	-5%

Data & analysis: Evidence, Thomson Reuters

Chart 1.03.06 Share of world agricultural biotechnology and engineering (including food) papers

Data & analysis: Evidence, Thomson Reuters

Commentary

Ireland had increased its outputs in agricultural biotechnology and engineering by 13% in 2007 in comparison with the average for the previous five years, but this increase is less than the group average and overall share of world outputs has dropped by 5%. This result may be aberrant however, as in 2007 a comparatively low number of papers were produced, following a particularly high number on 2006. Ireland output as a share of the eight 'charted nations' remains high – 10.88%.
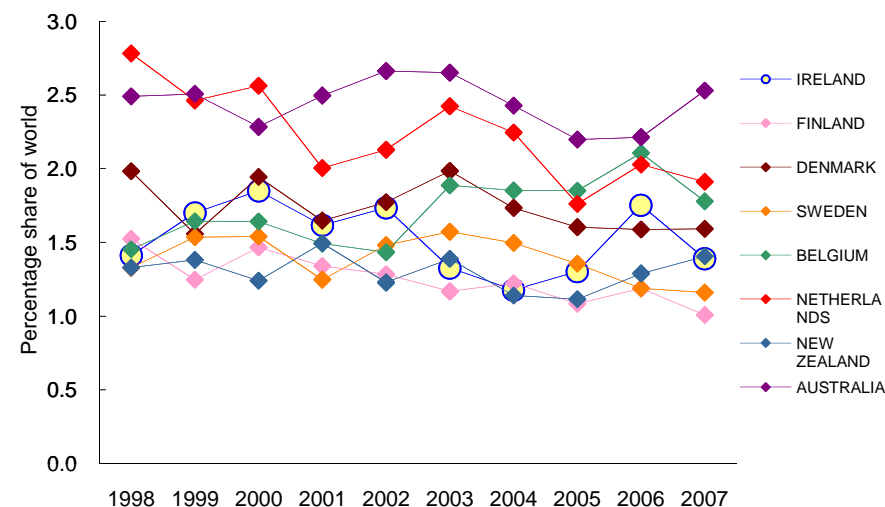
Agricultural biotechnology and engineering is a field where Ireland produces a relatively high percentage share of world outputs compared with other subject areas (around 1.5% of world share each year). The total number of papers produced is quite low however, and Ireland – together with other charted countries - show significant year to year variation. Taking the last six years as a whole, Ireland is in the middle of the comparator group.

Table 1.03.07 Number of agricultural sciences papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland papers	203	235	314	+33%
Group average papers	1,281	1,463	1,619	+11%
Ireland / Group average	0.16	0.16	0.19	+20%
Ireland rank within Group	15	17	17	⇔
Ireland as share of charted nations (%)	3.24	3.40	4.36	⇧
Ireland share of world (%)	0.57	0.59	0.70	+19%

Data & analysis: Evidence, Thomson Reuters

Chart 1.03.07 Share of world agricultural sciences papers
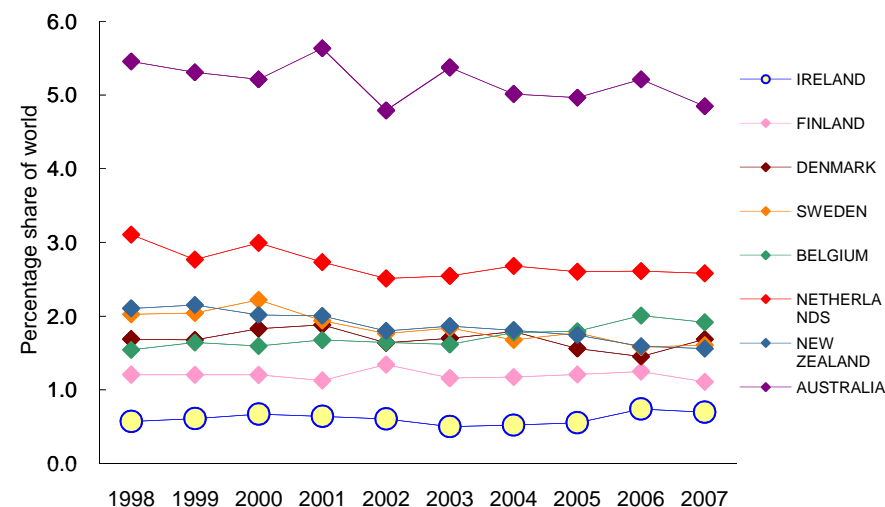
Data & analysis: Evidence, Thomson Reuters

Commentary

Ireland shows strong growth in the number of papers published in agricultural sciences (33%) which is 11% greater than the average for comparator countries. Ireland's share of the world total outputs has risen from 0.57% in 1998 to 0.70% by 2007. This is one of Ireland's comparatively strong disciplines. Ireland ranks 17th in terms of research volume amongst our comparator group, a drop from 15th in 1998. This drop reflects very strong growth by South Korea and Portugal, rather than any particular failing on the part of Irish researchers.

The chart shows that Ireland's share of world papers is small set against these comparator nations, but highlights consistent share of outputs over a long period. This is an area where the relative performance of the different countries is fairly static. Australia is well ahead of the other countries, though shows a consistent decline over the last ten years.

Table 1.03.08 Number of earth & environmental sciences papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland papers	179	292	357	+22%
Group average papers	2,254	3,000	3,534	+18%
Ireland / Group average	0.08	0.10	0.10	+4%
Ireland rank within Group	17	18	17	⇧
Ireland as share of charted nations (%)	2.02	2.32	2.73	⇧
Ireland share of world (%)	0.30	0.37	0.39	+7%

Data & analysis: Evidence, Thomson Reuters

Chart 1.03.08 Share of world earth & environmental sciences papers
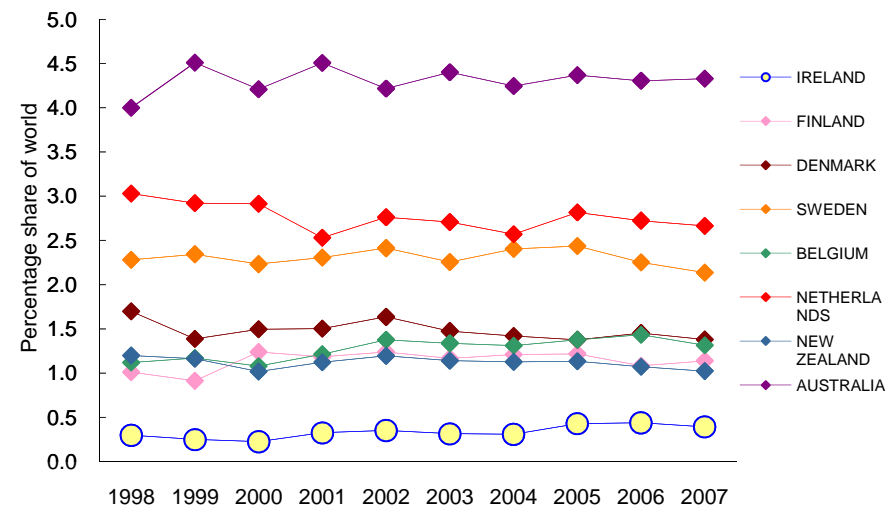
Data & analysis: Evidence, Thomson Reuters

Commentary

Ireland shows strong growth in the number of papers published in earth and environment science (22% increase, slightly greater than the group average). Ireland's share of total world output was only 0.39% in 2007, low in comparison with other disciplines, and in comparison with the 0.5% for environment papers (see section 1.02.04). Ireland has improved its ranking within the comparator group by one place over the last five years, now producing a higher percentage of world output than Singapore.

In terms of percentage share of world earth and environment science papers Ireland (0.39%) lags a long way behind its nearest comparators – New Zealand (1.02%), Finland (1.14%), Belgium (1.31%) and Denmark (1.38%). Ireland does however show a small but steady rise in its share of world output.

Table 1.03.09 Number of mathematics papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland papers	146	195	269	+38%
Group average papers	1,243	1,613	1,892	+17%
Ireland / Group average	0.12	0.12	0.14	+18%
Ireland rank within Group	18	18	17	⇧
Ireland as share of charted nations (%)	3.99	4.12	5.69	⇧
Ireland share of world (%)	0.39	0.41	0.51	+22%

Data & analysis: Evidence, Thomson Reuters

Chart 1.03.09 Share of world mathematics papers
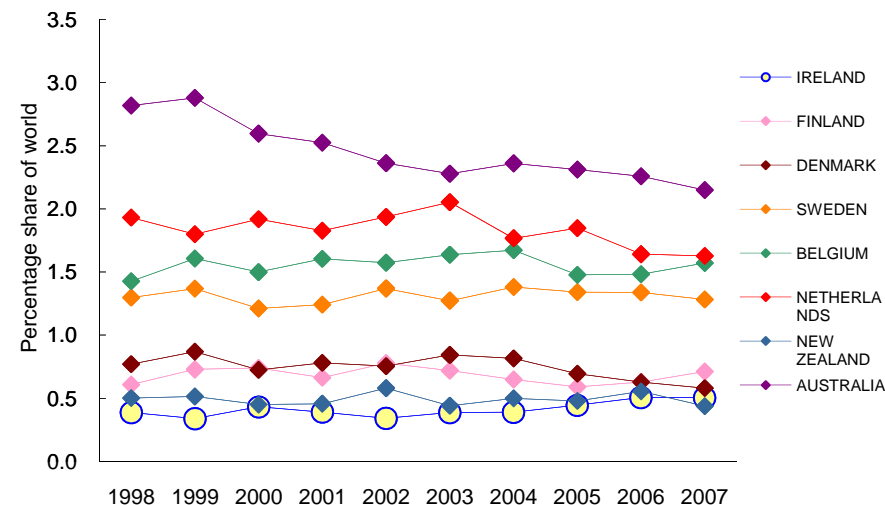
Data & analysis: Evidence, Thomson Reuters

Commentary

The number of mathematics papers produced in Ireland has increased by 38% in 2007 compared with the average of the previous five years, significantly (18%) better than the increase achieved on average by the comparator group. Ireland's share of world total output has risen to 0.51%, comparable to other Irish research areas.

Ireland's share of the total world mathematics output is growing faster than any of the other charted countries (22%) – the only other nation showing growth is Finland (6% growth in world share). The other countries in the chart have seen a decline in world share in 2007 compared with the previous five years. The Czech Republic – in many ways a country with a comparable research base – shows 13% growth in world share, while China's has increased its share by 36%.

Table 1.03.10 Number of physics and materials sciences papers

Chart 1.03.10 Share of world physics and materials sciences papers
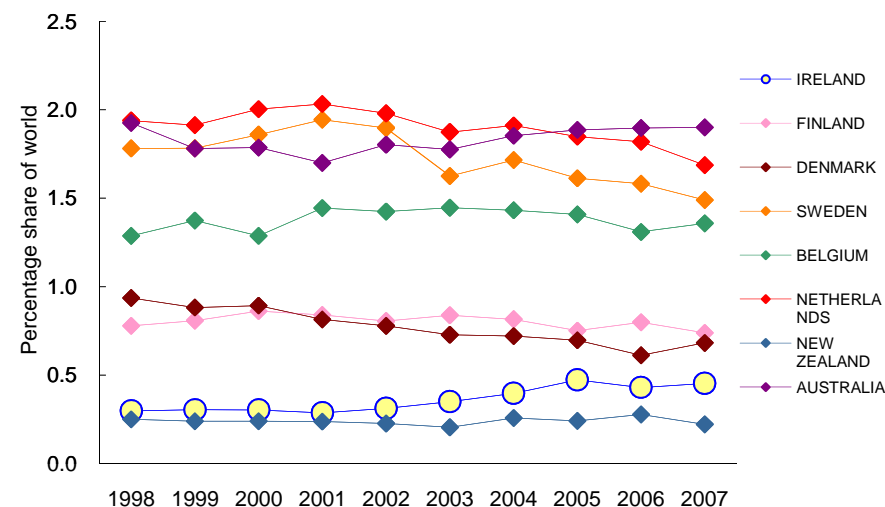
	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland papers	486	800	1,000	+25%
Group average papers	5,019	6,920	7,930	+15%
Ireland / Group average	0.10	0.12	0.13	+9%
Ireland rank within Group	17	17	17	⇔
Ireland as share of charted nations (%)	3.24	4.02	5.32	⇧
Ireland share of world (%)	0.30	0.39	0.45	+16%

Data & analysis: Evidence, Thomson Reuters

Data & analysis: Evidence, Thomson Reuters

Commentary

Ireland shows strong growth in the number of papers published in physics and material sciences (25%) which is 9% greater than the average for comparator countries. This rate of growth in the six years to 2007 is very strong, exceeded only by China (41%) and India (22%). By contrast three quarters of the countries in the comparator group suffered a net loss in their percentage of world share during the same period. Ireland's share of the world total outputs was only 0.30% in 1998, but by 2007 this had increased to 0.45%.

The chart shows that Ireland's share of physics and material sciences papers has increased strongly since 2001. Australia has achieved an increase in percentage share of world output of 3% over the same period, while all the other nations represented on the chart have seen their percentage share fall. New Zealand's volume of output was comparable with Ireland's ten years ago, but its trajectory since then has been downward. Given that successful physics and material science research is often dependant on substantial and well-established facilities these trends are likely to continue in coming years.

Table 1.03.11 Number of chemical sciences papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland papers	347	437	572	+31%
Group average papers	2,970	4,173	4,935	+18%
Ireland / Group average	0.12	0.10	0.12	+11%
Ireland rank within Group	18	17	17	⇔
Ireland as share of charted nations (%)	3.76	4.06	5.33	⇧
Ireland share of world (%)	0.31	0.32	0.38	+17%

Data & analysis: Evidence, Thomson Reuters

Chart 1.03.11 Share of world chemical sciences papers
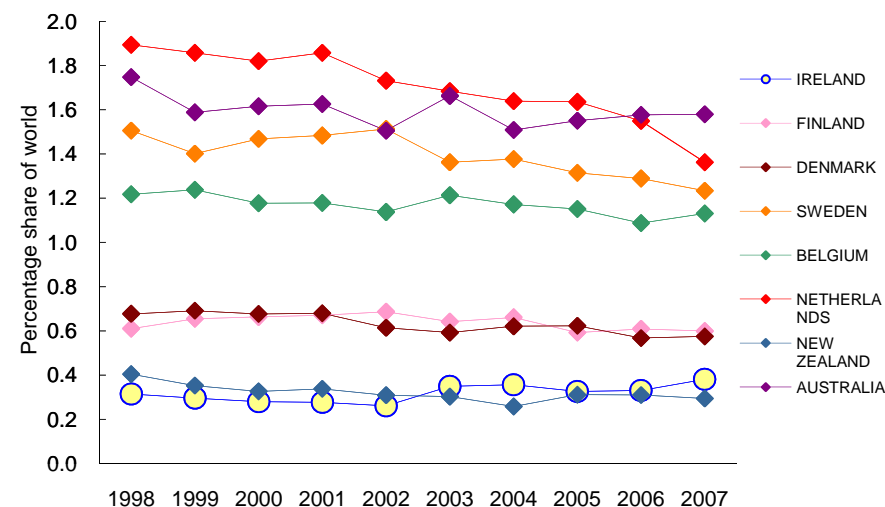
Data & analysis: Evidence, Thomson Reuters

Commentary

Ireland shows strong growth in the number of papers published in chemical sciences (31%) which is 11% greater than the average for comparator countries. This rate of growth in the six years to 2007 is very strong, exceeded only by China (31%). By contrast almost half of the countries in the comparator group suffered a net loss in their percentage of world share during the same period.

The chart shows that Ireland's percentage share of world chemical science papers, although very low (0.38% in 2007) has increased significantly over the ten year period to 2007. All the other charted comparator nations have suffered a decrease in their world percentage share, with the exception of Australia which has increased by only 1%. New Zealand's percentage share of world output was greater than Ireland's ten years ago, but its trajectory since then has been downward and New Zealand is now outperformed by Irish researchers.

Table 1.03.12 Number of nano-technology papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland papers	20	32	76	+139%
Group average papers	137	255	512	+101%
Ireland / Group average	0.15	0.12	0.15	+19%
Ireland rank within Group	15	16	13	⇧
Ireland as share of charted nations (%)	5.85	5.65	7.05	⇧
Ireland share of world (%)	0.52	0.48	0.61	+27%

Data & analysis: Evidence, Thomson Reuters

Chart 1.03.12 Share of world nano-technology papers
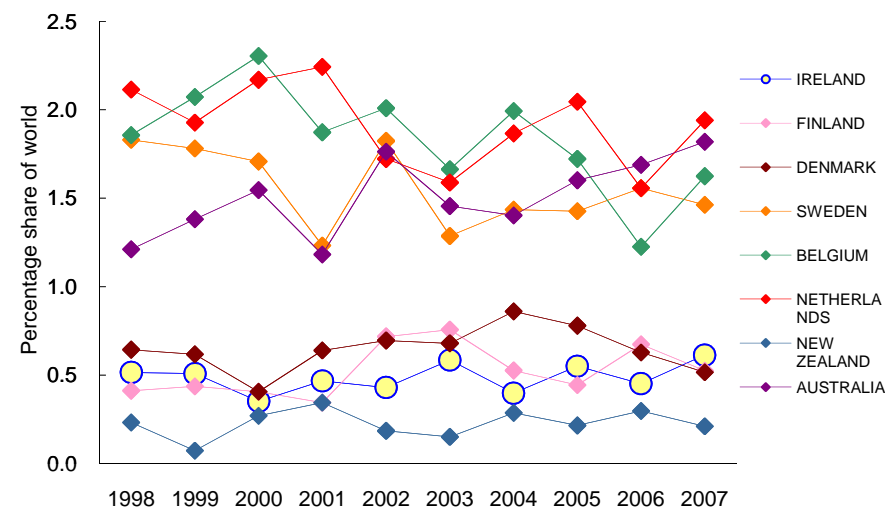
Data & analysis: Evidence, Thomson Reuters

Commentary

Although the figures presented in the table above suggest an enormous (139%) increase in Irish output, this is largely the result of a very high comparative result in 2007. Overall numbers are low, and so not too much should be ascribed to this figure. Nonetheless, looking at the overall picture Ireland has shown a consistent increase in volume of research outputs over the last ten years to a current high of 0.61% of total world output.

The comparator nations fall into two groups, and Ireland with percentage share of world total of 0.61 is now top of the lower group (which also comprises New Zealand, Finland and Denmark). Low overall numbers of papers mean that this situation is liable to change. It can be seen however that this is a research area where Ireland is performing well in terms of research volume.

Table 1.03.13 Number of computer and information sciences papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland papers	104	297	242	-18%
Group average papers	942	1,689	1,351	-20%
Ireland / Group average	0.11	0.18	0.18	+2%
Ireland rank within Group	17	17	16	⇧
Ireland as share of charted nations (%)	3.77	4.88	6.30	⇧
Ireland share of world (%)	0.40	0.61	0.67	+10%

Data & analysis: Evidence, Thomson Reuters

Chart 1.03.13 Share of world computer and information sciences papers
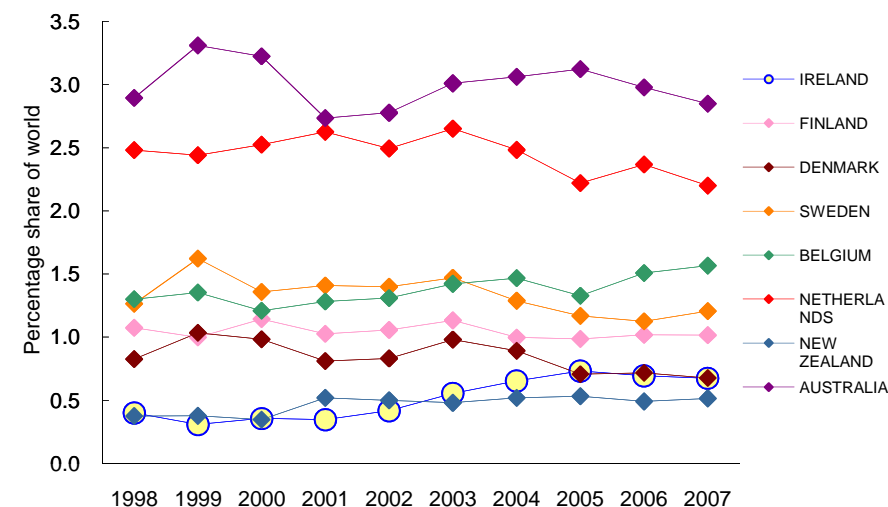
Data & analysis: Evidence, Thomson Reuters

Commentary

The 2007 figure for the number of Irish publications in computer and information sciences is 18% lower than the average for the period 2002-06. There was an even larger drop in output across the comparator group (20%), and it is encouraging to note that Ireland still produced 0.67% of world papers in 2007. This is the highest percentage world share for any of the Irish research areas examined in this report, with the exception of agriculture and agricultural biotechnology and engineering.

The curve for Irish publications reflects the way in which the number of Irish publications in computer and information sciences rose to a peak in 2005, and then decreased in 2006 and again in 2007. the volume of Irish outputs is the same as Denmark's, and greater than New Zealand. Ireland achieved a 10% increase in its share of total world publications comparing 2007, compared with the average for the five years 2002-06. Most comparator nations shown in the chart suffered a decrease in share over the same period, with the exception of Belgium which increased its share by 11%.

Table 1.03.14 Number of civil engineering papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland papers	10	24	59	+144%
Group average papers	231	411	476	+16%
Ireland / Group average	0.04	0.06	0.12	+110%
Ireland rank within Group	18	17	17	⇔
Ireland as share of charted nations (%)	1.49	2.54	4.37	⇧
Ireland share of world (%)	0.17	0.24	0.48	+104%

Data & analysis: Evidence, Thomson Reuters

Chart 1.03.14 Share of world civil engineering papers
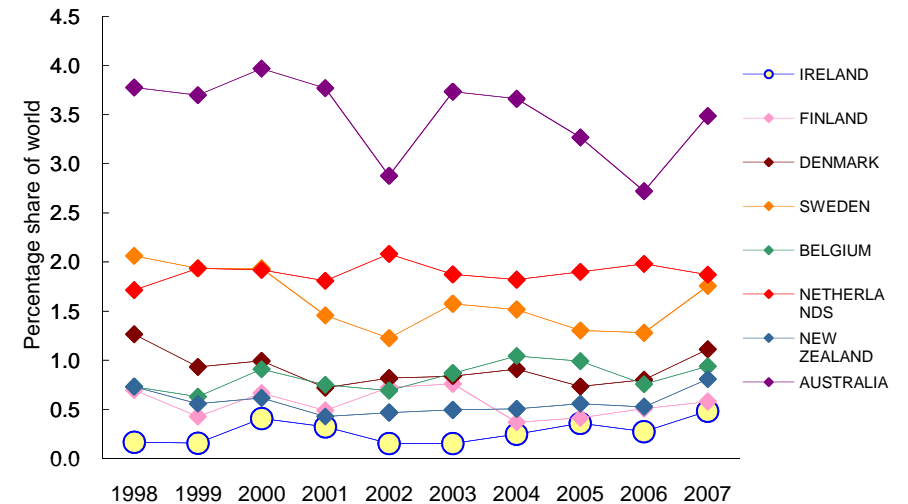
Data & analysis: Evidence, Thomson Reuters

Commentary

This analysis is presented for information but is based on very small volumes. Engineering research outputs are disseminated in a number of different ways, and as a result a lot of good research will not necessarily be found in articles and reviews. That said, in terms of these indicators Ireland has shown huge increases in output (144%) and percentage share of world output had increased to 0.48% by 2007 (from only 0.17% in 1998).

The chart suggests that the change in volume of Irish publications in civil engineering is the result of progressive improvement rather than just one or a few key papers. By 2007 Ireland was on a par with Finland, and starting to close the gap with New Zealand. This is good news, but the small volume makes this a vulnerable area.

Table 1.03.15 Number of electrical engineering, electronic engineering, information engineering papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland papers	161	246	408	+66%
Group average papers	1,721	2,123	2,584	+22%
Ireland / Group average	0.09	0.12	0.16	+36%
Ireland rank within Group	17	17	15	⇧
Ireland as share of charted nations (%)	3.50	4.06	6.17	⇧
Ireland share of world (%)	0.31	0.40	0.57	+40%

Data & analysis: Evidence, Thomson Reuters

Chart 1.03.15 Share of world electrical engineering, electronic engineering, information engineering papers
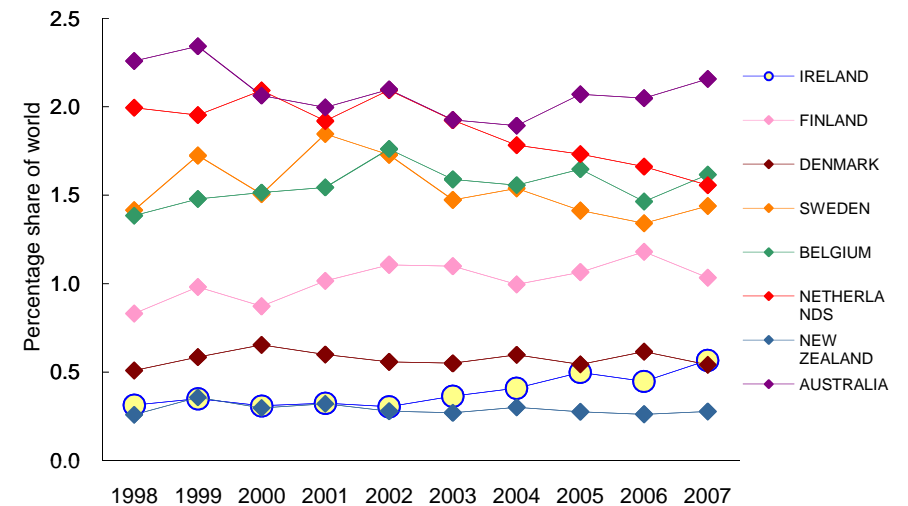
Data & analysis: Evidence, Thomson Reuters

Commentary

Ireland shows very strong growth in the number of papers published in electrical engineering, electronic engineering and information engineering (66% in the six years to 2007). This is the highest growth rate across our comparator group, matched only by China (also 66% growth). Ireland's share of world outputs has risen dramatically from 0.31% in 1998 to 0.57% in 2007. Ireland has moved up in the rankings to 15th position in terms of research volume, and is now ahead of both Denmark and the Czech Republic, as well as New Zealand and Northern Ireland.

The chart shows that Ireland's percentage share of world electrical engineering, electronic engineering and information engineering papers has increased strongly and since 2001 – an increase of 40%. In the same time frame Australia has achieved an increase in percentage share of world output of 7%, albeit starting from a much higher baseline (2.1% as opposed to 0.3%). All the other nations represented on the chart have seen their percentage share stay the same or fall. These branches of engineering are now amongst the top hitters in terms of research volume for the Irish custom research areas, scoring substantially better than engineering as a whole.

Table 1.03.16 Number of mechanical engineering papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland papers	90	113	104	-8%
Group average papers	1,088	1,302	1,440	+11%
Ireland / Group average	0.08	0.09	0.07	-17%
Ireland rank within Group	18	18	18	⇔
Ireland as share of charted nations (%)	3.43	3.54	3.00	⇩
Ireland share of world (%)	0.27	0.29	0.24	-17%

Data & analysis: Evidence, Thomson Reuters

Chart 1.03.16 Share of world mechanical engineering papers
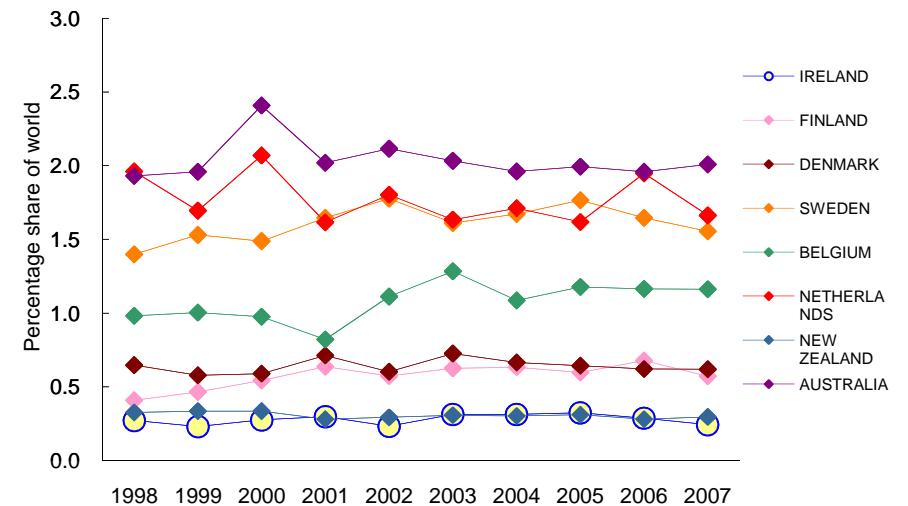
Data & analysis: Evidence, Thomson Reuters

Commentary

Mechanical engineering is a research area where Irish share of published research has remained very low over the last ten years – 0.27% in 1998, 0.24% in 2007. Other comparator counties have increased the number of publications, while Irish numbers have declined by 8%. In terms of ranking Ireland is at the bottom, with the exception of Northern Ireland.

This chart shows Ireland in a poor light in comparison with the other charted nations. New Zealand fares little better than Ireland, although in 2007 it did secure a significantly greater share of world papers (0.30% compared with Ireland's 0.24%). Irish mechanical engineering can derive some small comfort from the way that the comparator countries on the chart are all flat-lining in terms of their percentage share of world papers.

Table 1.03.17 Number of social sciences papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland papers	112	157	246	+57%
Group average papers	1,493	1,676	1,916	+14%
Ireland / Group average	0.08	0.09	0.13	+37%
Ireland rank within Group	16	16	15	⇧
Ireland as share of charted nations (%)	3.59	3.57	4.41	⇧
Ireland share of world (%)	0.34	0.42	0.58	+37%

Data & analysis: Evidence, Thomson Reuters

Chart 1.03.17 Share of world social sciences papers
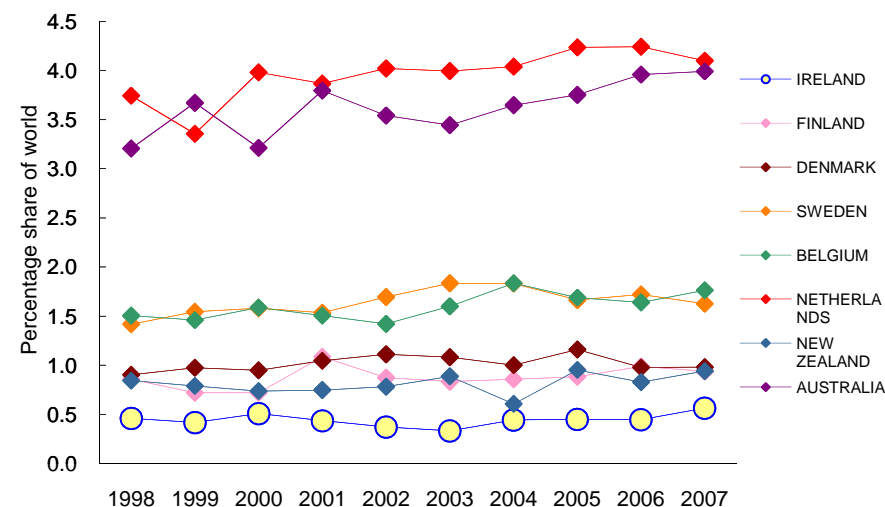
Data & analysis: Evidence, Thomson Reuters

Commentary

Growth in the number of social science papers produced by Irish authors has been phenomenal over the last ten years. From a very low base in 1998 (only 112 papers, or 0.34% of total world output) Ireland in 2007 produced 246 papers, or 0.58% of world output. Within Ireland, social science is now one of the stronger project research areas considered in this report. Share of the total world output has increased by 37% - the greatest improvement amongst any of this comparator group. These dramatic percentages must be interpreted in the light of publishing patterns within social sciences, where a lot of research is published in reports rather than as papers, and where patterns of research dissemination are rapidly evolving.

The chart shows that Ireland's share of world papers in sociology is small set against these comparator nations, but highlights steady growth in terms of percentage share of world publications. Comparator nations with a similar volume to Ireland, such as Denmark and Belgium, have increased their percentage share by 15-18%, but this is dwarfed by Ireland's 37% increase over the last six years. If current trajectories continue Ireland's world share will exceed that of Finland within the next few years.

Table 1.03.18 Number of economics and business papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland papers	81	85	143	+68%
Group average papers	799	941	1,142	+21%
Ireland / Group average	0.10	0.09	0.13	+39%
Ireland rank within Group	15	18	17	⇧
Ireland as share of charted nations (%)	3.55	2.86	3.78	⇧
Ireland share of world (%)	0.46	0.41	0.56	+38%

Data & analysis: Evidence, Thomson Reuters

Chart 1.03.18 Share of world economics and business papers
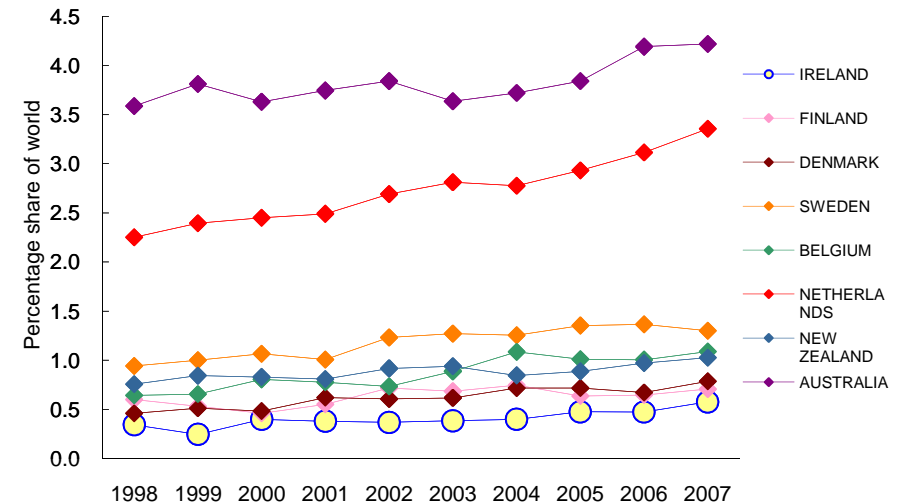
Data & analysis: Evidence, Thomson Reuters

Commentary

Ireland shows strong growth (68% increase in 2007 compared with the average 2002-06) in terms of economics and business publications. This headline figure needs to be interpreted carefully however, in the context of firstly a very low baseline (only 81 papers in 1998; 85 average 2002-06), and secondly a possibly aberrant figure for 2007. Irish inputs as a share of the world total also appears to have increased dramatically (by 38%). In terms of ranking within the comparator group Ireland has moved up to 17th position, ahead of the Czech Republic and Northern Ireland.

The chart shows that Ireland's share of world economics and business papers is small set against these comparator nations. Were it not for the high number of papers published in 2007 Ireland's share of world outputs overall would be fairly constant over the ten year period.

1.03.19 Number and share of world papers in 20 "project" research areas

Table 1.03.19 Number of psychology papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland papers	84	80	133	+66%
Group average papers	976	1,129	1,312	+16%
Ireland / Group average	0.09	0.07	0.10	+43%
Ireland rank within Group	12	14	14	⇔
Ireland as share of charted nations (%)	2.97	2.26	2.80	⇧
Ireland share of world (%)	0.38	0.32	0.46	+43%

Data & analysis: Evidence, Thomson Reuters

Chart 1.03.19 Share of world psychology papers
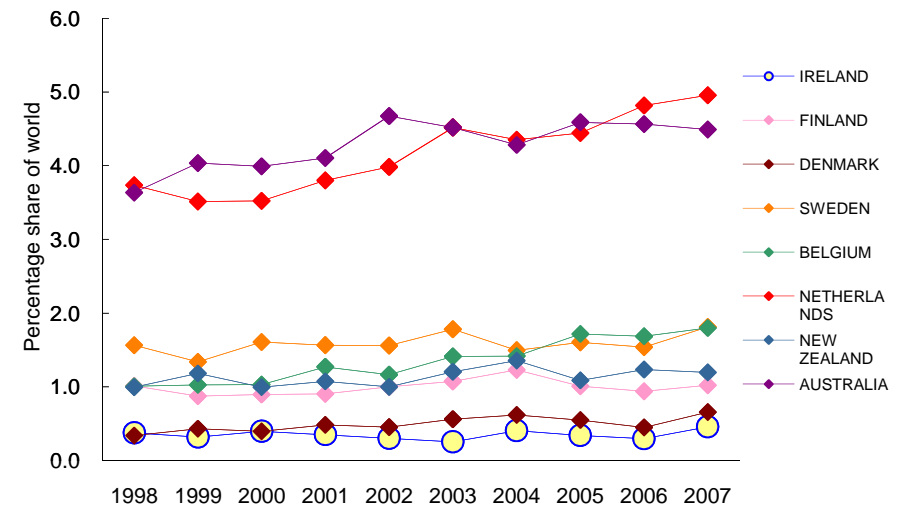
Data & analysis: Evidence, Thomson Reuters

Commentary

The headline figure in the table suggests significant increase in the volume of psychology publication to 2007, but this needs to be treated with care firstly because overall numbers of papers are low, and secondly because the figure for 2007 is unexpectedly high, with no increase in previous years leading up to this. Ireland's ranking within the group remains unaltered at 14th. Ireland's percentage share of world publications has risen to 0.46% which is slightly higher than the 0.4% share achieved in 2000.

The chart shows that Ireland's share of world psychology papers is small set against these comparator nations. Were it not for the relatively high number of papers published in 2007 Ireland's share of world outputs overall would be fairly constant over the ten year period. The Netherlands and Belgium are the only comparator countries which show an general increase in their percentage share of world publications.

Table 1.03.20 Number of humanities papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland papers	132	127	128	+1%
Group average papers	937	995	1,022	+3%
Ireland / Group average	0.14	0.13	0.13	-2%
Ireland rank within Group	10	12	11	⇧
Ireland as share of charted nations (%)	6.33	4.86	4.74	⇩
Ireland share of world (%)	0.54	0.49	0.49	-1%

Data & analysis: Evidence, Thomson Reuters

Chart 1.03.20 Share of world humanities papers
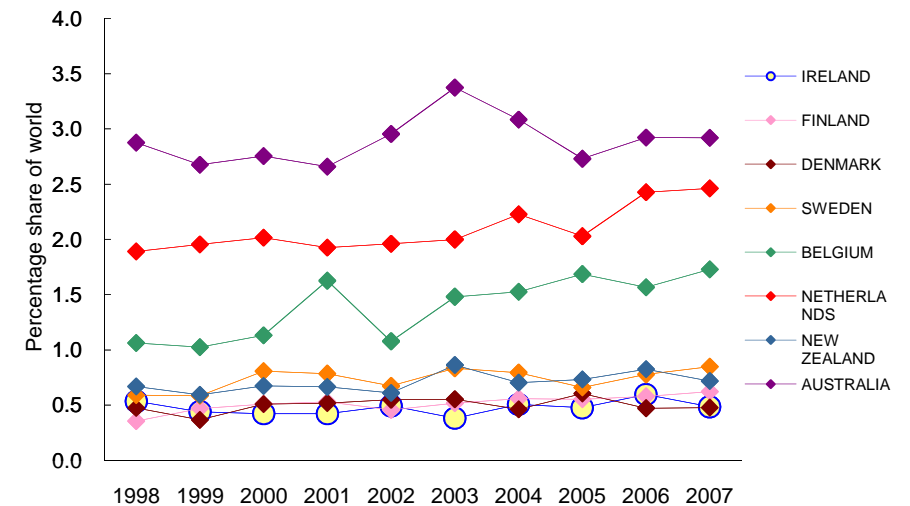
Data & analysis: Evidence, Thomson Reuters

Commentary

The number of humanities papers published by Irish authors has remained pretty much constant over the last ten years. Ireland's high ranking within the comparator group must be seen in the light of countries with relatively large research capacity (e.g. India, Brazil) which publish virtually no humanities research. These data should also be interpreted with care as in the humanities (and also for example in the performing arts) a high proportion of research outputs are in the form of books, chapters in books or non-publication formats.

Ireland's share of the world's humanities papers has remained at about 0.5% over the last ten years. Ireland's performance is very much on a par with a number of comparator countries – New Zealand, Denmark, Sweden and Finland.

Table 1.04 Total citations

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Citations to Ireland papers	52,581	26,414	2,258	-
Group average citations	534,352	258,215	16,351	-
Ireland / Group average	0.10	0.10	0.14	+35%
Ireland rank within Group	15	18	16	⇧
Ireland as share of charted nations (%)	3.01	3.24	3.92	⇧
Ireland share of world (%)	0.42	0.49	0.64	+32%

Data & analysis: Evidence, Thomson Reuters

Chart 1.04 Share of world citations
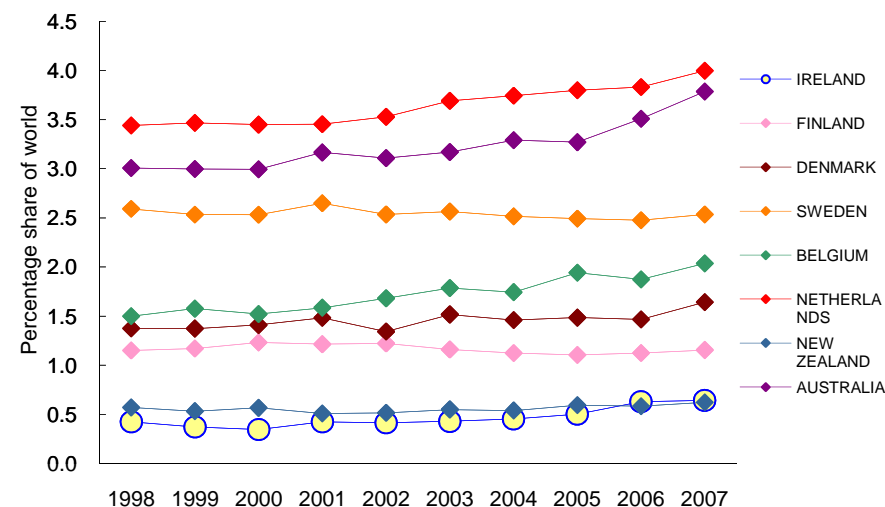
Data & analysis: Evidence, Thomson Reuters

Commentary

Ireland's share of world citations has increased from 0.42% to 0.64%. Its share of charted nations also increases. The total of cites to papers in each year increases over time, so actual year totals fall towards more recent years. A country's number and share of world citations is driven by both the quantity of its publication output and by the quality of that output. More papers means more items to cite and more references to be citations of other papers. This indicator is included here at total country level to illustrate Ireland's position, but this is not extended to each research area as the impact analysis (citations per paper) is more informative.

Ireland's rising trend in citation share can be seen, and it overtakes New Zealand in the most recent years. Several other nations also show a rising performance while Sweden and Finland have a static share. The relative change for Ireland puts it in a dynamic group with Denmark and Australia. The absolute totals mean that Ireland is unlikely to change its rank significantly within the comparator group but the change in citation share compared to change in output share means that its overall impact will have improved.

Table 1.05 Citation impact

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland citation impact	1.20	1.15	1.26	+9%
Group average citation impact	0.99	1.07	1.15	+8%
Ireland / Group average	1.21	1.08	1.09	+1%
Ireland rank within Group	8	9	8	⇧
Ireland rank within charted nations	5	6	5	⇧

Data & analysis: Evidence, Thomson Reuters

Chart 1.05 Citation impact
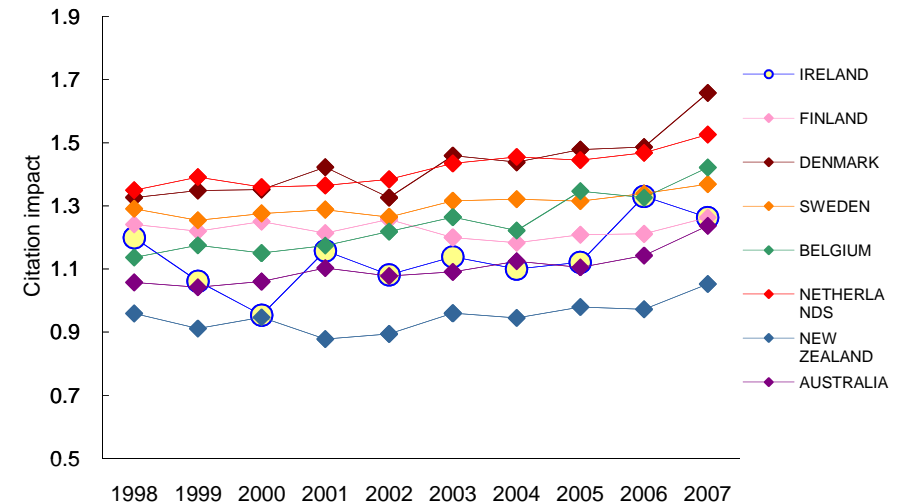
Data & analysis: Evidence, Thomson Reuters

Commentary

This table summarises Irish citation impact across all disciplines. The rate at which Irish research is being cited is increasing in line with the increase achieved on average by the nineteen countries in the larger comparator group. While Ireland was 18th in terms of research volume (see table 1.01 above), it is ranked 8th in terms of citation impact – so although the volume is small the impact or quality of the research is good. Newly emergent research economies – China, Brazil, India, South Korea – produce more research but the impact of this research is low – well below world average.

Ireland is ranked 5th amongst the group of eight 'charted' nations in terms of research impact – consistently ahead of New Zealand and pretty much on a par with Australia and Finland. Apart from research published in 2000 the impact of Irish work has always, on average, been better than world average (citation impact = 1.00) and shows a positive trend in the last two years for which data are available (2006-07).

Table 1.06.01 Citation impact of clinical papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland citation impact	0.95	1.18	1.34	+14%
Group average citation impact	1.02	1.07	1.15	+7%
Ireland / Group average	0.94	1.10	1.16	+6%
Ireland rank within Group	13	9	5	⇧
Ireland rank within charted nations	8	6	3	⇧

Data & analysis: Evidence, Thomson Reuters

Chart 1.06.01 Citation impact of clinical papers
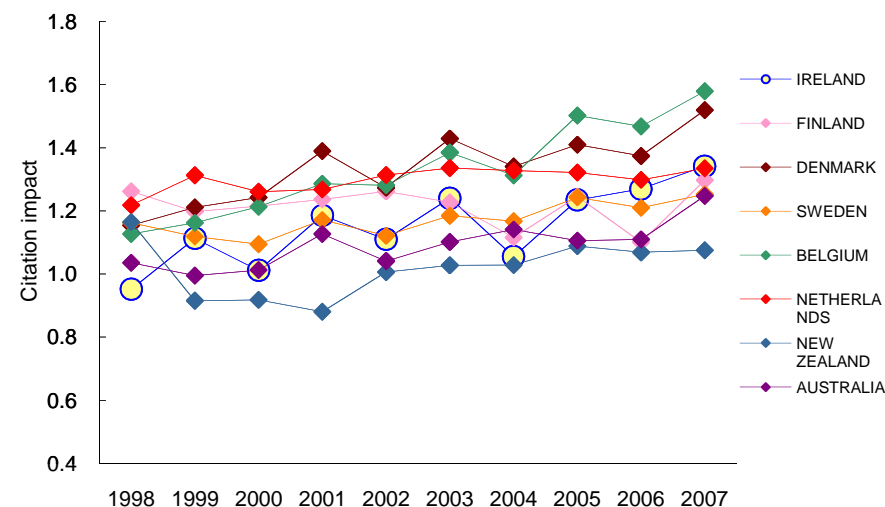
Data & analysis: Evidence, Thomson Reuters

Commentary

Clinical research in Ireland shows an impressive increase in impact (14%), well ahead of the average increase achieved by comparator nations. Ireland is ranked 5th out of 19 amongst the comparator group – on a par with the USA and ahead of the Netherlands, Finland and the UK. Combined with the significant increase in research volume (see Table 1.02.01) this suggests that clinical research in Ireland is performing well.

In 1998 Ireland started at the bottom of the group of charted nations, rising to third position by 2007. Improvement over the period 2005-07 was consistent. Research from the Netherlands, which initially had far more impact than Irish research, is now having roughly the same impact. Clinical research from New Zealand, produced in roughly the same volume as Irish clinical research, has consistently had less impact than Irish research.

Table 1.06.02 Citation impact of health & medically-related papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland citation impact	1.08	1.51	1.82	+21%
Group average citation impact	1.14	1.18	1.29	+9%
Ireland / Group average	0.95	1.28	1.41	+10%
Ireland rank within Group	12	4	3	⇧
Ireland rank within charted nations	8	2	2	⇔

Data & analysis: Evidence, Thomson Reuters

Chart 1.06.02 Citation impact of health & medically-related papers
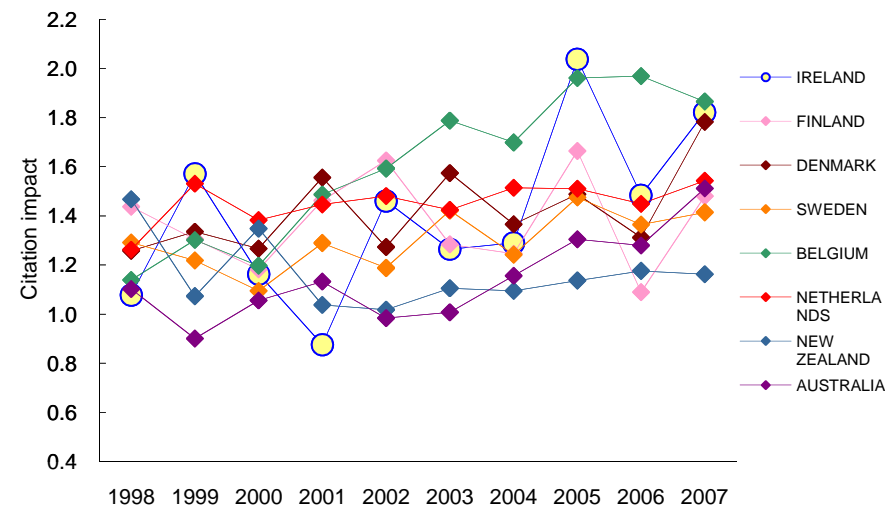
Data & analysis: Evidence, Thomson Reuters

Commentary

Health and medically-related research from Ireland is being cited at a high rate (citation impact = 1.82). The impact of Irish research had increased by 21% over the last six years, a 10% greater rate of increase than that achieved by the comparator group as a whole. Ireland is ranked 3rd amongst the 19 comparator nations, just behind Scotland and Belgium. This high ranking is particularly impressive as this is an area where Irish research volume has also increased strongly (see Table 1.02.02).

Citation rates for health and medically-related research from Ireland show an overall improvement over the ten year period 1998-2007, with particularly impressive results in 2007. Irish research is now ranked 2nd for citation impact within the charted group of comparator nations.

Table 1.06.03 Citation impact of biological sciences papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland citation impact	1.49	1.02	1.09	+7%
Group average citation impact	0.92	0.98	1.08	+10%
Ireland / Group average	1.61	1.04	1.01	-3%
Ireland rank within Group	1	10	11	⇩
Ireland rank within charted nations	1	6	7	⇩

Data & analysis: Evidence, Thomson Reuters

Chart 1.06.03 Citation impact of biological sciences papers
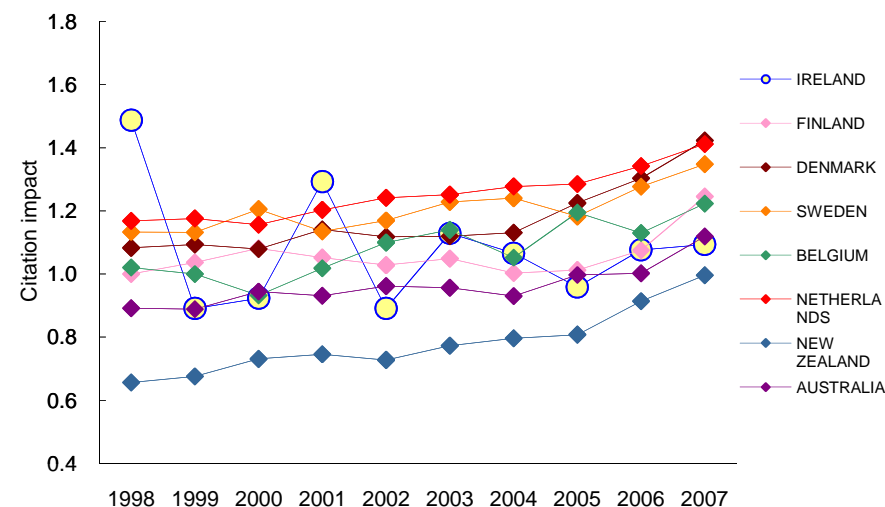
Data & analysis: Evidence, Thomson Reuters

Commentary

Although citation rates for biological sciences have increased by 7% over the last six years, this rate of increase is 3% lower than the increase achieved by other countries in the group. As a result Ireland's rank (which was 1st in 1998 at an exceptional peak driven by a small number of papers) has fallen from 10th recently to 11th behind the USA and most of the European countries, but still ahead of the Asian comparator countries.

From an exceptional high in 1998, the impact of Irish biological sciences research has settled out to a moderate level. In 1999, 2000 and 2002 Irish research had less impact than world average. While the volume of Irish research has increased over the last five years the quality has not. Irish research has more impact than research from New Zealand, but if trends continue as at present this position will not be maintained for much longer.

Table 1.06.04 Citation impact of environment papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland citation impact	0.85	0.96	1.13	+17%
Group average citation impact	0.98	1.10	1.16	+6%
Ireland / Group average	0.87	0.88	0.97	+10%
Ireland rank within Group	13	12	11	⇧
Ireland rank within charted nations	8	8	8	⇔

Data & analysis: Evidence, Thomson Reuters

Chart 1.06.04 Citation impact of environment papers
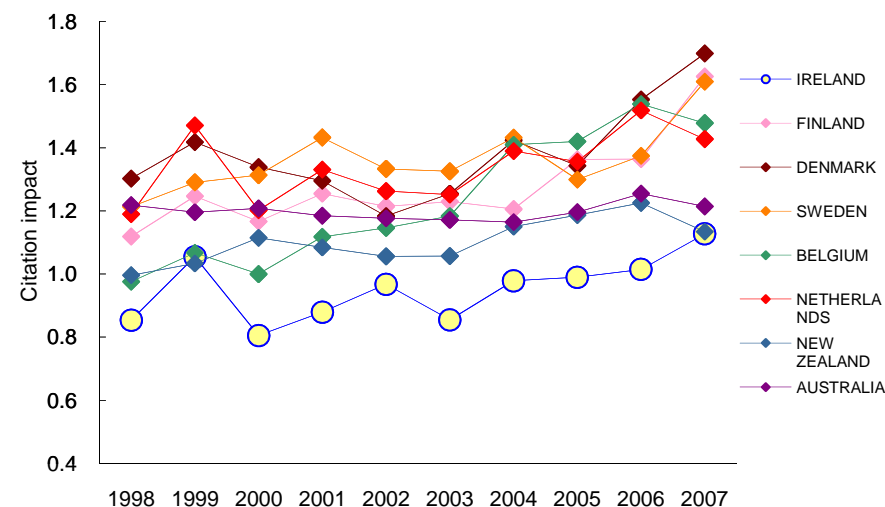
Data & analysis: Evidence, Thomson Reuters

Commentary

The impact of Irish environment research has increased at a faster rate (17%) than the average rate of increase within the comparator group (6%). Even so, Ireland still ranks only 11th within the comparator group behind the USA and most of the European countries, but still ahead of the Asian comparator countries.

The impact of Irish environment research is showing steady increase from a low base. In 2006 and 2007 impact has been higher than world average. The gap between Irish research and research carried out in the other charted countries is still significant.

Table 1.06.05 Citation impact of mathematics papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland citation impact	0.83	0.94	1.68	+77%
Group average citation impact	1.03	1.07	1.16	+8%
Ireland / Group average	0.81	0.88	1.45	+64%
Ireland rank within Group	14	14	3	⇧
Ireland rank within charted nations	8	8	3	⇧

Data & analysis: Evidence, Thomson Reuters

Chart 1.06.05 Citation impact of mathematics papers
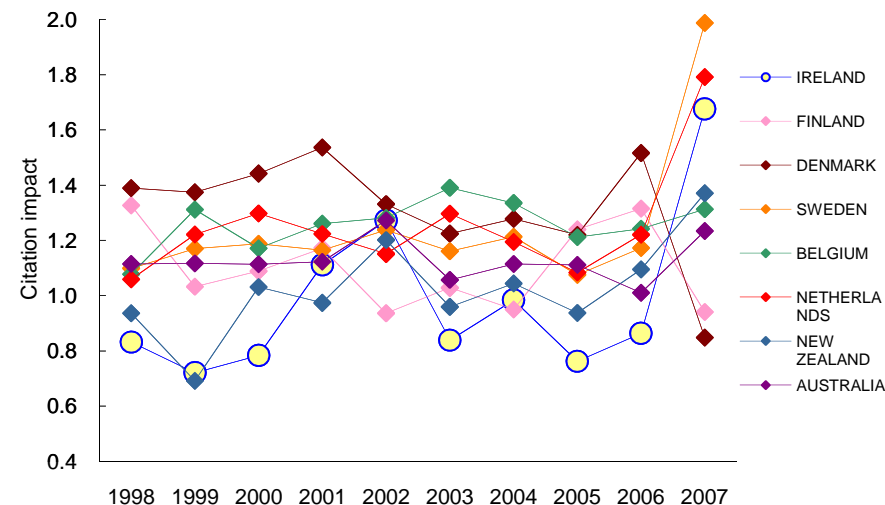
Data & analysis: Evidence, Thomson Reuters

Commentary

Irish mathematics research produced in 2007 has been highly cited (citation impact = 1.68) in comparison with research produced in earlier years, and as a result Ireland is ranked 3rd amongst the 19 comparator nations, behind only the Netherlands and Sweden (research from these countries also achieved a possibly aberrantly high citation rate in 2007).

For most of the years prior to 2007 Irish mathematics research was cited at a low rate – less than world average in all years other than 2001 and 2002. Over this period Irish mathematics has been towards the bottom, or at the bottom, of the group of charted nations in terms of research impact.

Table 1.06.06 Citation impact of physical sciences papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland citation impact	1.19	1.23	1.45	+17%
Group average citation impact	1.05	1.12	1.23	+9%
Ireland / Group average	1.13	1.10	1.18	+7%
Ireland rank within Group	6	7	7	⇔
Ireland rank within charted nations	4	3	3	⇔

Data & analysis: Evidence, Thomson Reuters

Chart 1.06.06 Citation impact of physical sciences papers
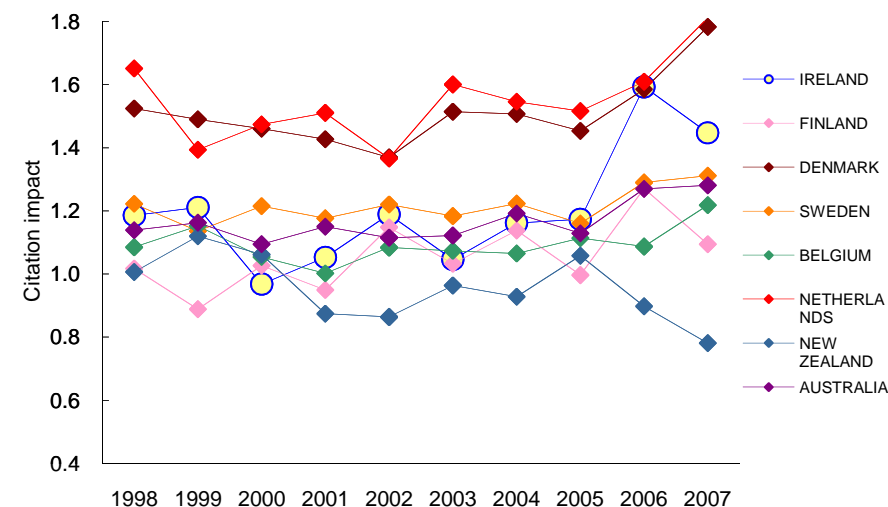
Data & analysis: Evidence, Thomson Reuters

Commentary

Physical sciences research from Ireland is fairly well cited and the rate of citation has increased in recent years – a more rapid increase than that achieved by comparator nations. Ireland is now ranked 7th amongst the 19 in the group, ahead of a number of comparable research economies including Sweden, Australia, Belgium, Finland and New Zealand. This healthy citation position is complemented by the 26% increase in research volume illustrated in table 1.02.06.

This chart suggests that physical sciences research from Ireland is consistently being cited at rates similar to the average achieved by research from the charted group of nations. The last two years (2006 and 2007) suggest an even better performance, leaving Ireland ahead of all other countries with the exception of the Netherlands and Denmark.

Table 1.06.07 Citation impact of engineering papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland citation impact	1.29	1.18	1.21	+3%
Group average citation impact	1.01	1.08	1.11	+3%
Ireland / Group average	1.28	1.09	1.10	+0%
Ireland rank within Group	4	6	7	⇩
Ireland rank within charted nations	3	5	5	⇔

Data & analysis: Evidence, Thomson Reuters

Chart 1.06.07 Citation impact of engineering papers
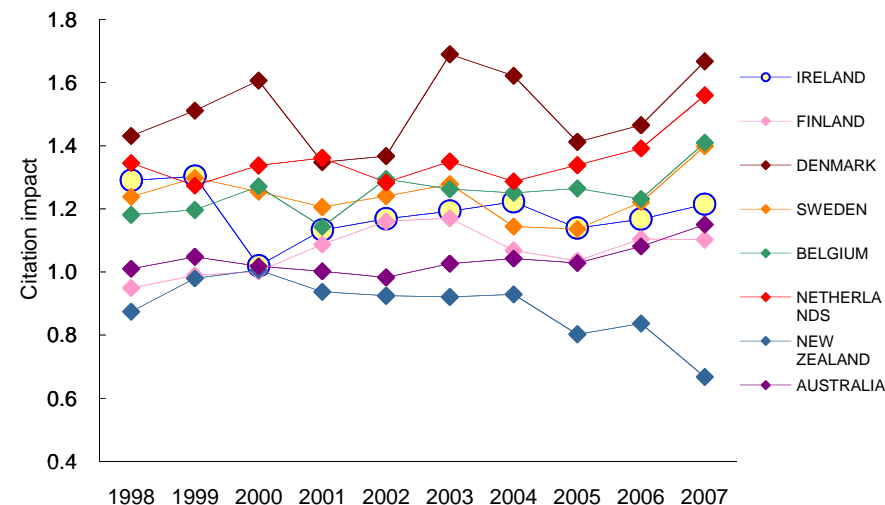
Data & analysis: Evidence, Thomson Reuters

Commentary

Irish citation rates in engineering are increasing at a rate equal to the average rate of increase for the comparator group. In the rankings Ireland has slipped to 7th place behind the UK, but ahead of Australia, Czech Republic, North Ireland, Finland, Scotland, Portugal, New Zealand and the Asian countries. This healthy citation position is complemented by the 46% increase in research volume illustrated in table 1.02.07.

This chart demonstrates the way in which engineering research from Ireland has consistently maintained healthy citation performance over the last ten years. Ireland is securely located in the middle of the charted group of nations.

Table 1.06.08 Citation impact of social science papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland citation impact	0.63	0.80	0.82	+2%
Group average citation impact	0.90	0.94	0.90	-4%
Ireland / Group average	0.70	0.85	0.91	+6%
Ireland rank within Group	16	12	12	⇔
Ireland rank within charted nations	8	8	7	⇧

Data & analysis: Evidence, Thomson Reuters

Chart 1.06.08 Citation impact of social science papers
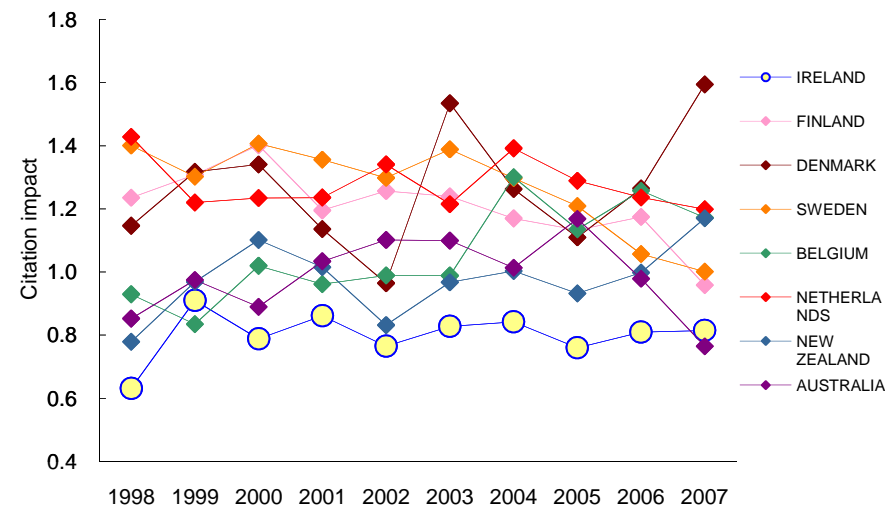
Data & analysis: Evidence, Thomson Reuters

Commentary

Indexed journal articles in social science research are dominated by the USA and UK, where large and active communities extensively co-cite and hence elevate the world average. Comparative citation rates for Irish social science research are well below that world average, but so are average citation rates for other members of the comparator group. Even so Ireland's ranking at 12th out of the 19 nations is poor, ahead only of Australia and the Asian nations.

The chart illustrates the way in which Irish social science research has consistently failed to achieve citation rates on a par with the other charted nations. Ireland crept into 7th position in 2007 only by dint of a very poor result from Australia (citation impact = 0.76) rather than any improvement in Irish research performance.

Table 1.06.09 Citation impact of business papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland citation impact	0.63	0.79	1.27	+62%
Group average citation impact	0.75	0.88	0.91	+4%
Ireland / Group average	0.85	0.90	1.40	+56%
Ireland rank within Group	14	14	5	⇧
Ireland rank within charted nations	7	8	1	⇧

Data & analysis: Evidence, Thomson Reuters

Chart 1.06.09 Citation impact of business papers
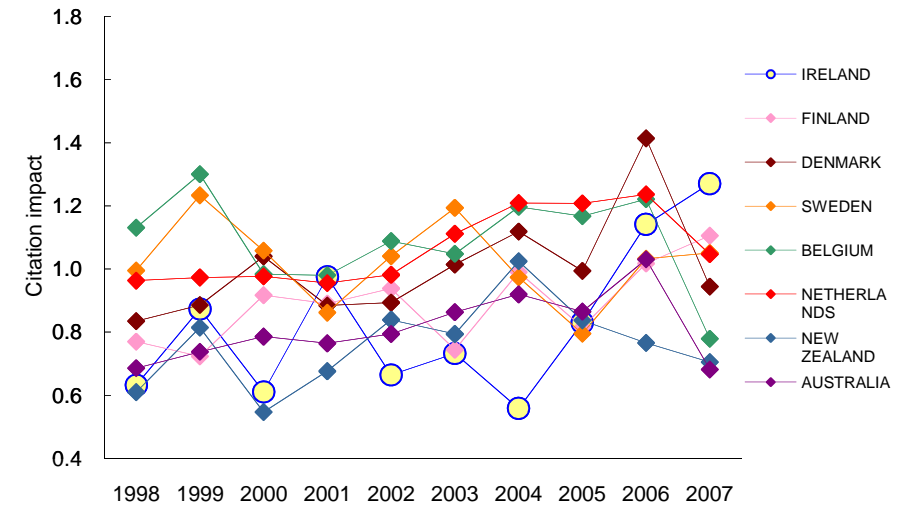
Data & analysis: Evidence, Thomson Reuters

Commentary

Irish business research has shown strong improvement in terms of rates of citation since 2004. From a low base (citation impact = 0.56 – much lower than world average) Irish papers are now being cited at better than world average (citation impact = 1.27 in 2007). This improvement is complemented by the increase in research volume illustrated in table 1.02.09. Ireland's ranking within the comparator group has shot up to 5th, behind Scotland, the USA, Northern Ireland and the UK.

The chart shows how citation of Irish business research has improved over the four years leading up to 2007. Ireland is now top of the charted nations in terms of this indicator – a situation which also existed in 2001.

1.06.10 Citation impact relative to world baselines in 10 main research areas

Table 1.06.10 Citation impact of humanities papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland citation impact	0.60	1.10	1.06	-4%
Group average citation impact	1.03	1.19	1.28	+8%
Ireland / Group average	0.58	0.93	0.82	-11%
Ireland rank within Group	14	10	10	⇔
Ireland rank within charted nations	8	6	4	⇧

Data & analysis: Evidence, Thomson Reuters

Chart 1.06.10 Citation impact of humanities papers
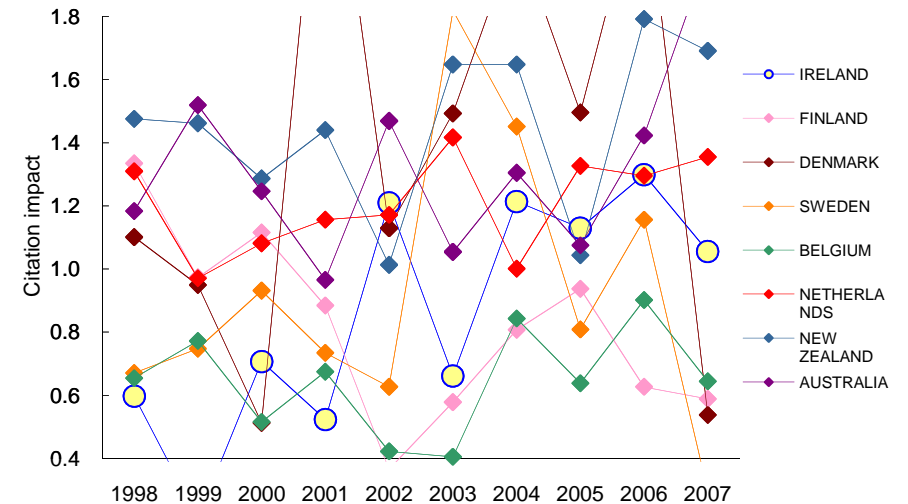
Data & analysis: Evidence, Thomson Reuters

Commentary

Humanities research is often disseminated through books and monographs than journals, so citation impact is a weak indicator. Ireland's research produced in 2007 was less cited than that published between 2002 and 2006. Research from comparator countries was more highly cited in 2007. Despite this, Ireland has maintained its ranking within the comparator group at 10th position, and improved its position amongst the charted nations to 4th, due to very poor citation rates for Danish, Swedish and Portuguese research. These data need to be interpreted cautiously, and the total volume of Irish humanities research is very low (average 36 papers per year – see Indicator 1.02.10).

It is immediately apparent that citation rates for humanities research carried out by workers in the different charted nations show large variations. Within this confused picture it can be seen that Irish performance shows an overall positive trend, from well below world average from 1998 – 2001, to generally at or above world average from 2002 onwards. Between 2004 and 2007 Ireland was ranked around the middle of the charted group.

Table 1.07.01 Citation impact of clinical medicine papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland citation impact	0.97	1.14	1.36	+19%
Group average citation impact	1.11	1.14	1.24	+9%
Ireland / Group average	0.87	1.00	1.09	+9%
Ireland rank within Group	13	12	9	⇧
Ireland rank within charted nations	8	8	7	⇧

Data & analysis: Evidence, Thomson Reuters

Chart 1.07.01 Citation impact of clinical medicine papers
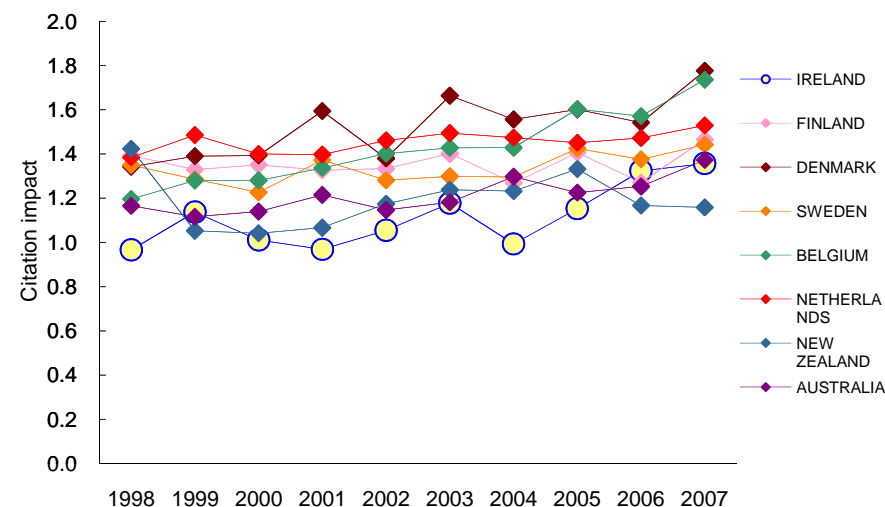
Data & analysis: Evidence, Thomson Reuters

Commentary

Clinical medicine research published by Irish authors in 2007 has been cited 19% more frequently than papers published in the previous five years. This rate of increase is well ahead of the average increase achieved by comparator nations. Ireland is ranked 9th out of 19 amongst the comparator group – almost on a par with the USA and Australia, and ahead of the UK (including Northern Ireland) and New Zealand. Combined with the 30% increase in research volume over the same period (see Table 1.03.01) this suggests that clinical medicine research in Ireland is performing well.

The rate at which Irish research has been cited over the ten year period 1998-2007 was poor in comparison with the other charted nations, but shows a marked improvement between 2005 – 2007, ending almost level with Denmark with a citation impact of 1.36. Citation rates are now well ahead of rates achieved by research published by New Zealand authors, who produce a volume of clinical medicine research similar to that produced by Irish researchers.

Table 1.07.02 Citation impact of pre-clinical & health papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland citation impact	1.13	1.20	1.23	+2%
Group average citation impact	0.90	0.97	0.98	+0%
Ireland / Group average	1.26	1.23	1.26	+2%
Ireland rank within Group	5	3	2	⇧
Ireland rank within charted nations	2	1	1	⇔

Data & analysis: Evidence, Thomson Reuters

Chart 1.07.02 Citation impact of pre-clinical & health papers
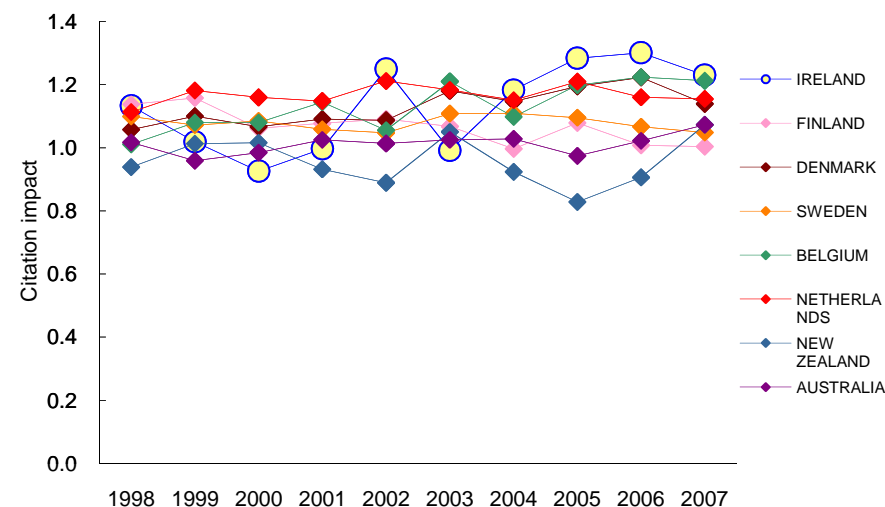
Data & analysis: Evidence, Thomson Reuters

Commentary

Ireland is ranked 2nd out of 19 within our comparator group in terms of the rate at which pre-clinical and health papers are being cited, beaten only by the USA. This is a particularly good result given that the volume of papers produced has increased by 39% over the last six years (see Table 1.03.02).

Ireland started and ended the time period 1998 – 2007 at the head of this group of charted nations with some disappointing results in 2000, 2001 and 2003 when citation rates were only at, or were slightly below, world average. Performance in the last four years (2004 – 2007) has been much stronger.

Table 1.07.03 Citation impact of biological sciences: Organismal biology papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland citation impact	0.92	1.06	1.32	+25%
Group average citation impact	0.94	1.04	1.13	+8%
Ireland / Group average	0.98	1.02	1.17	+15%
Ireland rank within Group	11	10	7	⇧
Ireland rank within charted nations	7	7	4	⇧

Data & analysis: Evidence, Thomson Reuters

Chart 1.07.03 Citation impact of biological sciences: Organismal biology papers
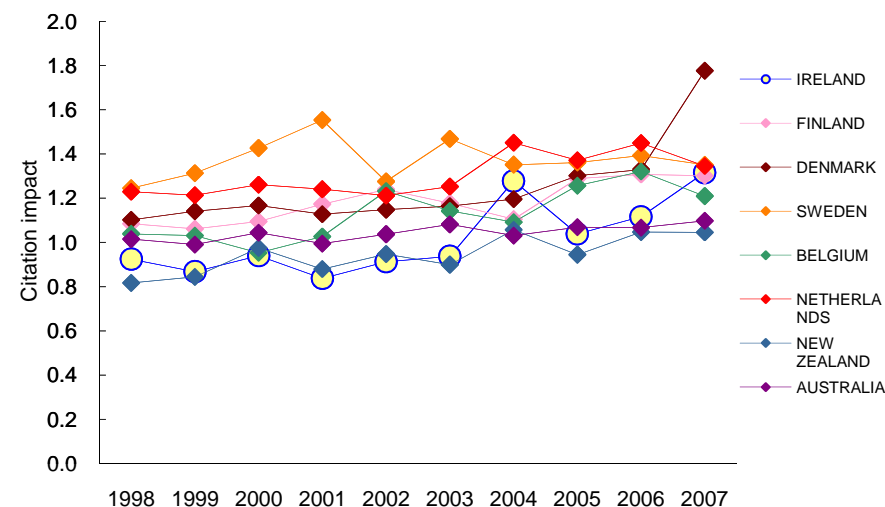
Data & analysis: Evidence, Thomson Reuters

Commentary

Citation rates for Organismal biology papers from Ireland have improved by 25% over the last six years, and over this period have been consistently higher than rates achieved for Irish Biological sciences as a whole. Citation rates for Irish research are now better than rates achieved by research published by workers in the USA. Combined with the 43% increase in research volume over the same period (see Table 1.03.03) this suggests that Organismal biology research in Ireland is performing well.

Citation rates for Irish research published over the six year period 1998 – 2003 was poor (below world average), but a marked improvement can be seen for research published in 2004 and 2007. Ireland now ranks 4th in this group of charted nations, just behind Sweden and the Netherlands, well behind Denmark, but ahead of Belgium, Australia and New Zealand.

Table 1.07.04 Citation impact of biological sciences: Molecular & cellular biology papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland citation impact	1.68	1.16	1.07	-8%
Group average citation impact	0.89	0.95	0.98	+3%
Ireland / Group average	1.89	1.22	1.09	-11%
Ireland rank within Group	1	5	11	⇩
Ireland rank within charted nations	1	2	7	⇩

Data & analysis: Evidence, Thomson Reuters

Chart 1.07.04 Citation impact of biological sciences: Molecular & cellular biology papers
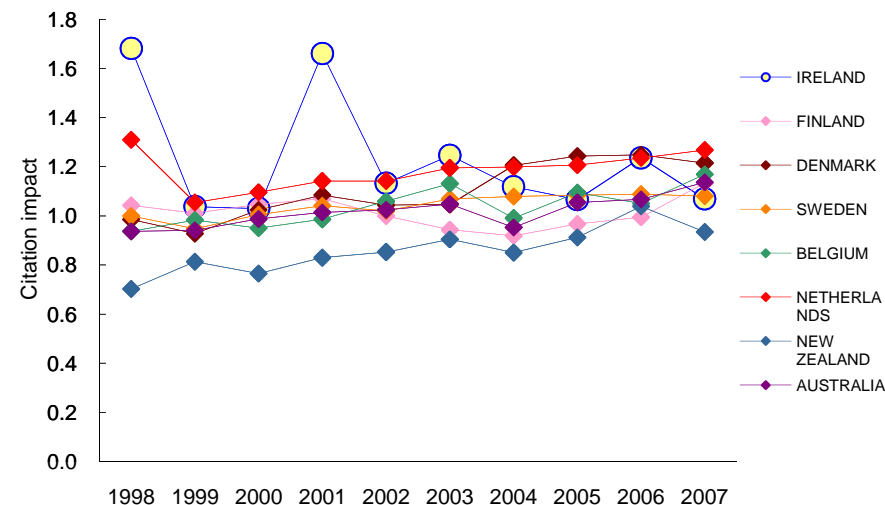
Data & analysis: Evidence, Thomson Reuters

Commentary

Citation rates for Molecular and cellular biology papers publicised by Irish authors in 1998 and 2001 were high (1.68 and 1.66 – well above world average) but more recently papers in this subject have had much less impact, meaning Ireland is now ranked 11th out of 19 amongst our comparator group, well behind both the USA and most of the European comparator nations. Volume of Irish papers in this subject have greatly increased (by 43% – see Table 1.03.04) but these data suggest effort might have better been put into producing fewer papers which achieved a greater impact.

The chart shows a general downward trend in citation rates, to the point where papers published in 2007 achieve a citation impact of only 1.07. In terms of 2007 papers Ireland was ranked 7th in the group, behind all the charted comparators with the exception of New Zealand.

Table 1.07.05 Citation impact of biotechnology papers

Chart 1.07.05 Citation impact of biotechnology papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland citation impact	1.47	1.19	0.81	-32%
Group average citation impact	1.04	1.12	1.20	+7%
Ireland / Group average	1.42	1.06	0.68	-36%
Ireland rank within Group	1	9	15	⇩
Ireland rank within charted nations	1	5	8	⇩

Data & analysis: Evidence, Thomson Reuters
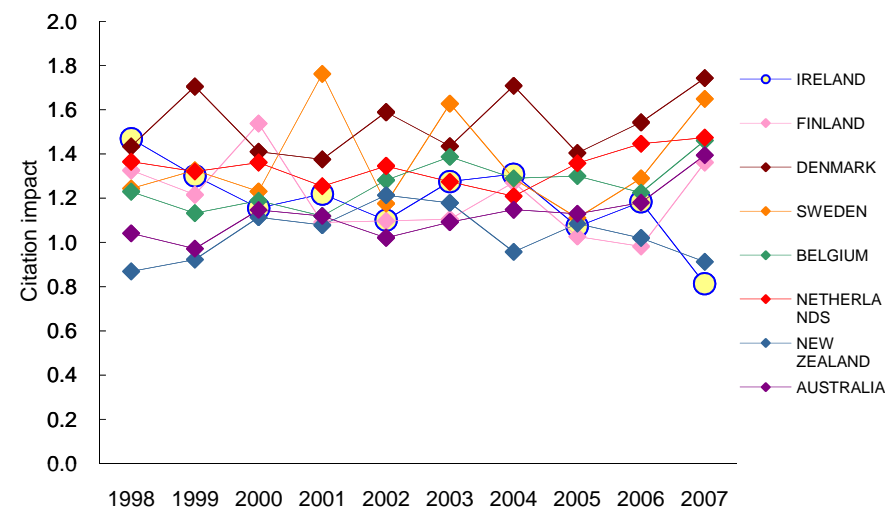
Data & analysis: Evidence, Thomson Reuters

Commentary

Irish papers in biotechnology produced in 1998 were well cited, with a citation impact of 1.47. This placed Ireland ahead of all the comparator nations in the group. Subsequently citation rates dropped alarmingly, and papers published in 2007 achieved a citation impact of only 0.81 – well below world average. Ireland is now at the bottom of the rankings except in relation to the Asian nations which achieve only low impact for their research.

The chart shows a steady decline in citation rates achieved by Irish research, meaning that Ireland has gradually performed worse and worse in comparison with the charted nations. The number of Irish biotechnology papers have greatly increased (by 41% over the last six years – see Table 1.03.05) but these data suggest effort might have better been put into producing fewer papers which achieved a greater impact.

Table 1.07.06 Citation impact of agricultural biotechnology and engineering (including food) papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland citation impact	1.51	1.18	1.42	+20%
Group average citation impact	1.21	1.16	1.14	-2%
Ireland / Group average	1.25	1.02	1.25	+23%
Ireland rank within Group	6	11	5	⇧
Ireland rank within charted nations	4	6	4	⇧

Data & analysis: Evidence, Thomson Reuters

Chart 1.07.06 Citation impact of agricultural biotechnology and engineering (including food) papers
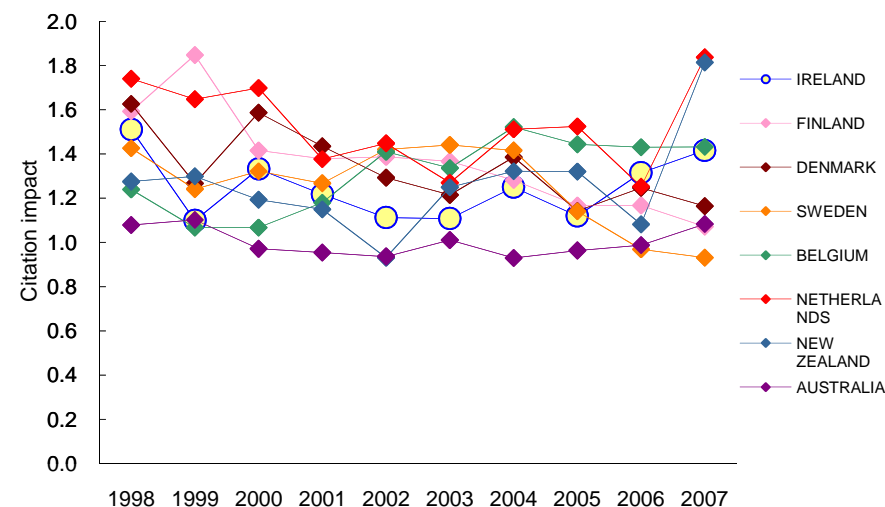
Data & analysis: Evidence, Thomson Reuters

Commentary

Citation rates for agricultural biotechnology and engineering papers produced by Irish authors have improved by 20% over the last six years; over the same period citation rates for comparator nations as a whole have fallen by 2%. For research published in 2007 Ireland is now ranked 5th out of 19 within our comparator group, ahead of the USA and the UK, and also ahead of most of the other European comparator nations.

Ireland started and ended the time period 1998 – 2007 with satisfactory citation rates (citation impact of 1.51 for papers published in 1998; and of 1.42 for papers published in 2007). Comparatively poor citation rates were achieved by papers published in 2002, 2003 and 2005. The upward trend in recent years means that Ireland is now ranked 4th amongst the charted group, almost level with Belgium but trailing the Netherlands and New Zealand.

Table 1.07.07 Citation impact of agricultural sciences papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland citation impact	1.02	1.27	1.92	+51%
Group average citation impact	1.18	1.22	1.51	+24%
Ireland / Group average	0.87	1.04	1.27	+22%
Ireland rank within Group	15	9	6	⇧
Ireland rank within charted nations	8	6	3	⇧

Data & analysis: Evidence, Thomson Reuters

Chart 1.07.07 Citation impact of agricultural sciences papers
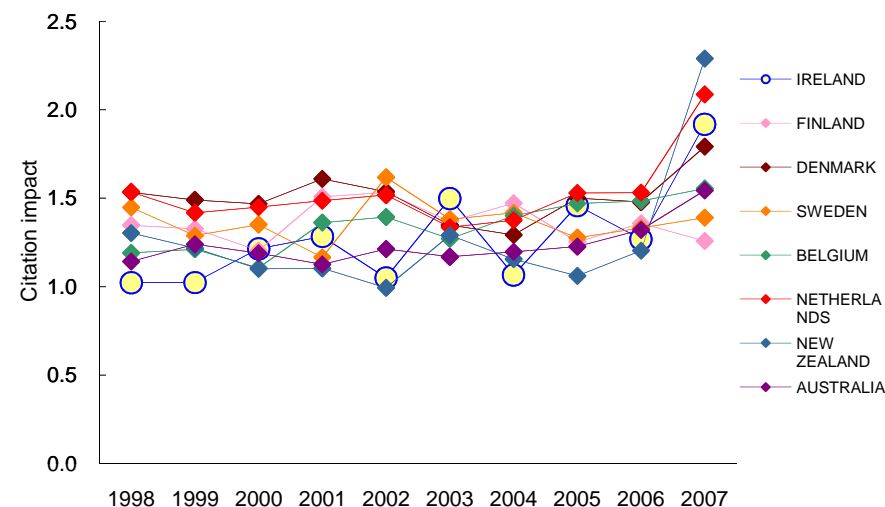
Data & analysis: Evidence, Thomson Reuters

Commentary

Irish agricultural science papers published in 1998, 1999 and 2002 achieved modest citation rates (just above world average), but in more recent years citation rates have improved significantly and Ireland now ranks 6th out of our 19 comparator nations. In 2007 Irish research achieved a citation impact of 1.92 – well above world average.

In common with four of the other charted nations, Irish research published in 2007 achieved a much higher citation rate than publications from previous years. The overall trend for Irish research is positive in comparison with other charted countries.

Table 1.07.08 Citation impact of earth & environmental sciences papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland citation impact	0.88	1.07	1.13	+6%
Group average citation impact	1.00	1.11	1.15	+4%
Ireland / Group average	0.88	0.96	0.98	+1%
Ireland rank within Group	14	12	11	⇧
Ireland rank within charted nations	8	8	8	⇔

Data & analysis: Evidence, Thomson Reuters

Chart 1.07.08 Citation impact of earth & environmental sciences papers
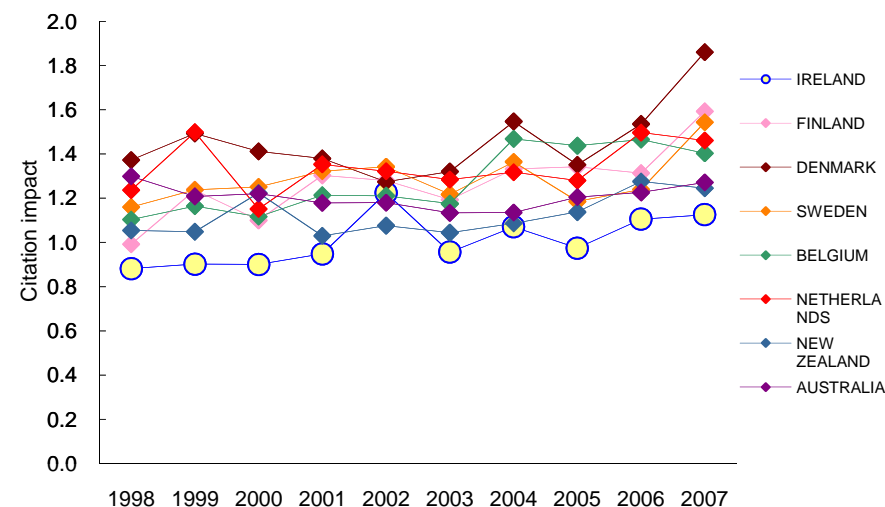
Data & analysis: Evidence, Thomson Reuters

Commentary

The impact of Irish earth and environment research has improved in recent years but prior to 2005 average citation rates were less than world average. Ireland ranks only 11th within the comparator group behind the USA and most of the European countries, but still ahead of the Asian comparator countries and Brazil.

The chart shows that the impact of Irish earth and environment research is gradually improving. Ireland however is still bottom of the rankings amongst the charted nations. The volume of Irish papers in this subject has greatly increased (by 33% over the last six years - see Table 1.03.07) but these data suggest effort might have better been put into producing fewer papers which achieved a greater impact.

Table 1.07.09 Citation impact of mathematics papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland citation impact	0.79	0.93	1.32	+42%
Group average citation impact	0.98	1.09	1.13	+3%
Ireland / Group average	0.81	0.85	1.17	+37%
Ireland rank within Group	16	12	6	⇧
Ireland rank within charted nations	8	8	4	⇧

Data & analysis: Evidence, Thomson Reuters

Chart 1.07.09 Citation impact of mathematics papers
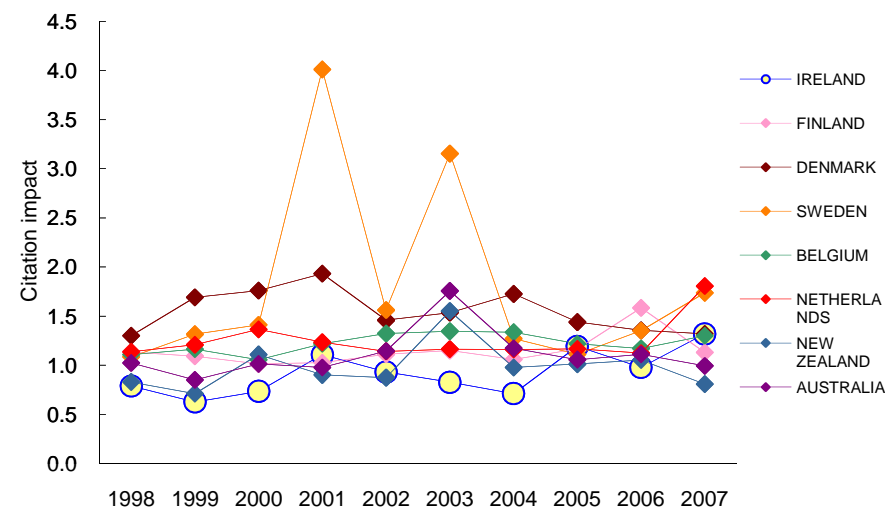
Data & analysis: Evidence, Thomson Reuters

Commentary

The impact of Irish mathematics research has improved in recent years but prior to 2005 average citation rates were less than the world average citation impact (= 1.0). As a result of citations of papers published in 2007 Ireland has moved up the rankings to 6th position, ahead of the USA and many European comparator nations and of Australia and New Zealand.

The Chart show Ireland improving its ranking in terms of citation of mathematics papers published in 2005 and 2007. For most of the ten year period 1998 – 2007 Irish mathematics has been towards the bottom, or at the bottom, of the group of charted nations in terms of research impact. A good result for 2007 ranks Ireland 4th amongst the charted countries.

Table 1.07.10 Citation impact of physics & materials sciences papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland citation impact	1.21	1.47	1.51	+3%
Group average citation impact	1.08	1.22	1.34	+9%
Ireland / Group average	1.12	1.20	1.13	-6%
Ireland rank within Group	7	6	7	⇩
Ireland rank within charted nations	4	3	3	⇔

Data & analysis: Evidence, Thomson Reuters

Chart 1.07.10 Citation impact of physics & materials sciences papers
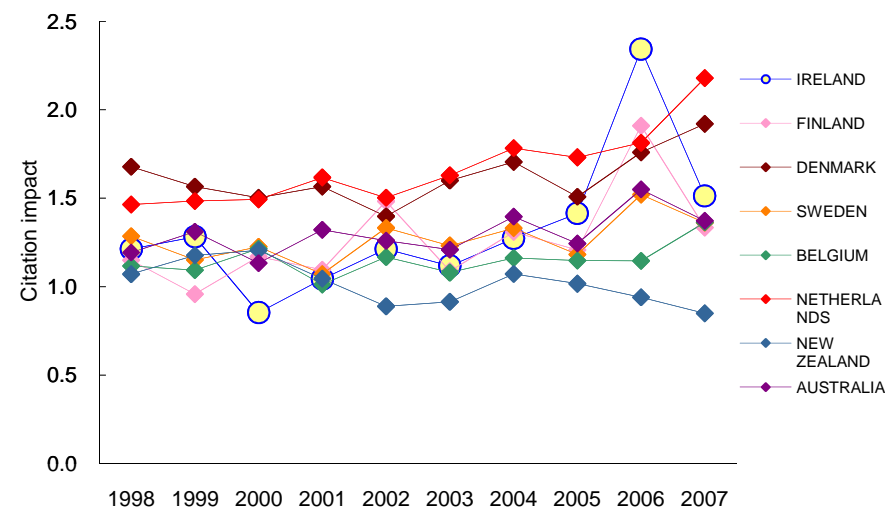
Data & analysis: Evidence, Thomson Reuters

Commentary

Physics and material sciences research from Ireland is fairly well cited and the rate of citation has slightly increased in recent years. Ireland is ranked 7th amongst the 19 in the comparator group, ahead of a number of comparable research economies including Sweden, Australia, Belgium, Finland, Portugal, Czech Republic and New Zealand. This healthy citation position is complemented by the 25% increase in research volume illustrated in table 1.03.10.

This chart suggests that physics and material sciences research from Ireland is generally being cited at rates similar to the average achieved by research from the charted group of nations. Papers published in 2000 were poorly cited (less than world average) while those published in 2006 were particularly well cited, with a citation impact of 2.34.

Table 1.07.11 Citation impact of chemical sciences papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland citation impact	1.26	1.25	1.55	+24%
Group average citation impact	1.07	1.11	1.21	+9%
Ireland / Group average	1.18	1.12	1.29	+14%
Ireland rank within Group	5	6	3	⇧
Ireland rank within charted nations	4	3	1	⇧

Data & analysis: Evidence, Thomson Reuters

Chart 1.07.11 Citation impact of chemical sciences papers
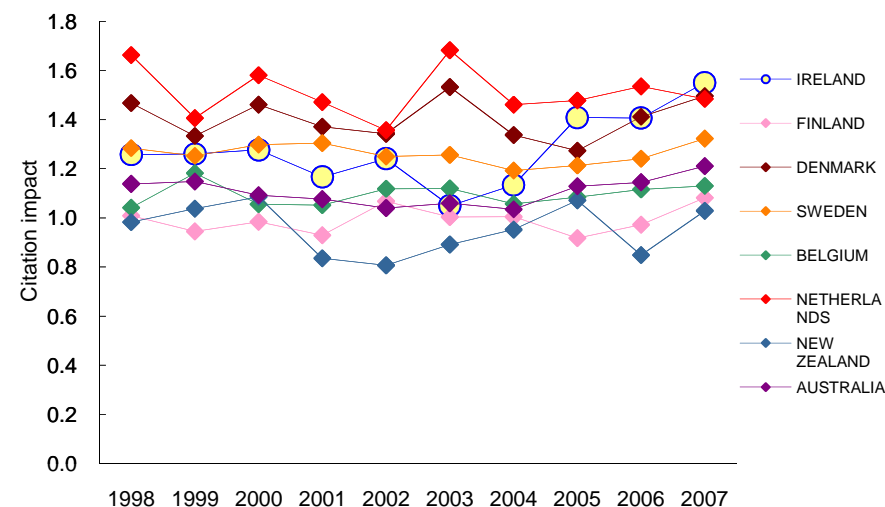
Data & analysis: Evidence, Thomson Reuters

Commentary

Citation of Irish chemical sciences papers has increased by 24% over the last six years to an average citation impact of 1.55 in 2007. Complemented by the 31% increase in research volume (see Table 1.03.11) this suggests that Irish research in this area is in a healthy condition. Irish research published in 2007 ranks 3rd within the comparator group in terms of citation impact, just behind Scotland and Northern Ireland.

The chart shows that citation rates for Irish research were in the mid range of rates achieved by charted nations over the period 1998 – 2004. The position improved for papers published in 2005 and 2006, and in 2007 Irish publications were more highly cited than papers from any of the charted nations.

Table 1.07.12 Citation impact of nano-technology papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland citation impact	1.17	1.30	1.24	-5%
Group average citation impact	1.11	0.93	1.08	+16%
Ireland / Group average	1.06	1.40	1.15	-18%
Ireland rank within Group	7	3	7	⇩
Ireland rank within charted nations	5	2	5	⇩

Data & analysis: Evidence, Thomson Reuters

Chart 1.07.12 Citation impact of nano-technology papers
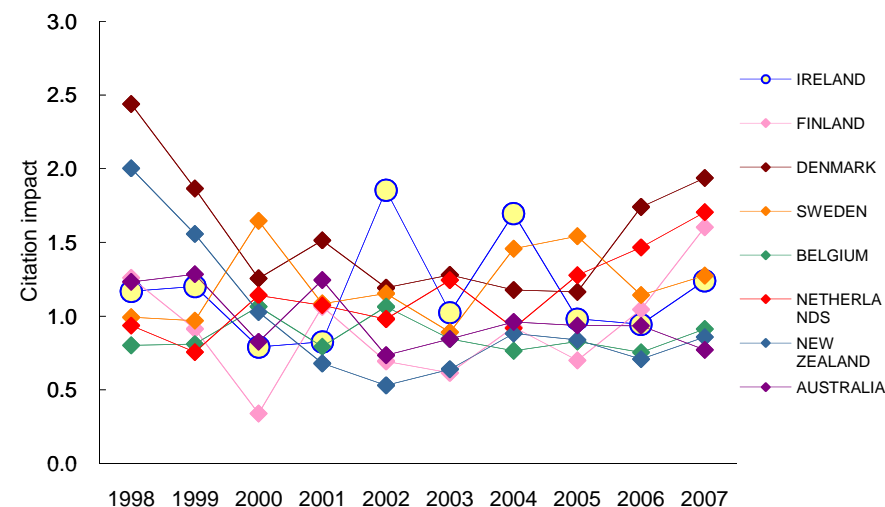
Data & analysis: Evidence, Thomson Reuters

Commentary

Citation rates for Irish nano-technology papers are significantly better than those achieved on average by other countries within the comparator group. Irish papers published in the five year period 2002 – 2006 received more citations than those from comparator countries with the exception of USA and Denmark.

The small number of papers published in nano-technology mean that the chart shows a lot of variation between years. Irish papers produced in 2002 and 2004 were particularly well cited (citation impact of 1.85 and 1.70 respectively) but in general Irish papers have been in the mid range in terms of citation, although in 2000, 2001, 2005 and 2006 citation rates were less than world average.

Table 1.07.13 Citation impact of computer and information sciences papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland citation impact	0.67	0.78	0.65	-17%
Group average citation impact	0.91	1.01	1.02	+1%
Ireland / Group average	0.74	0.78	0.64	-18%
Ireland rank within Group	16	15	16	⇩
Ireland rank within charted nations	8	8	7	⇧

Chart 1.07.13 Citation impact of computer and information sciences papers
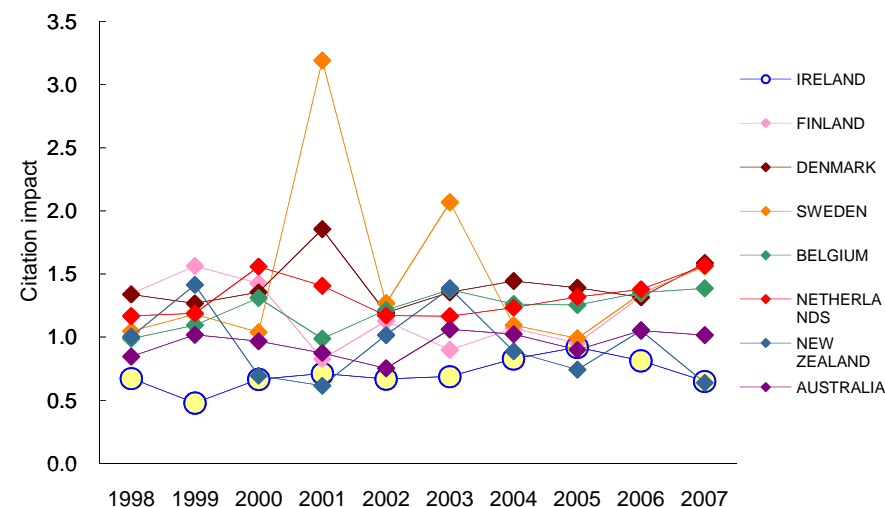
Commentary

Citation rates for Irish computer and information sciences papers are well below world average and Ireland is towards the bottom of the comparator group rankings.

Irish citation rates are at or towards the bottom of the chart in all years for which data has been collected. Ireland only ranks better than last as a result of years when papers from New Zealand have been cited at an extremely low rate.

Table 1.07.14 Citation impact of civil engineering papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland citation impact	0.88	0.75	1.53	+104%
Group average citation impact	0.96	1.20	1.16	-3%
Ireland / Group average	0.92	0.62	1.32	+112%
Ireland rank within Group	11	19	5	⇧
Ireland rank within charted nations	7	8	4	⇧

Data & analysis: Evidence, Thomson Reuters

Chart 1.07.14 Citation impact of civil engineering papers
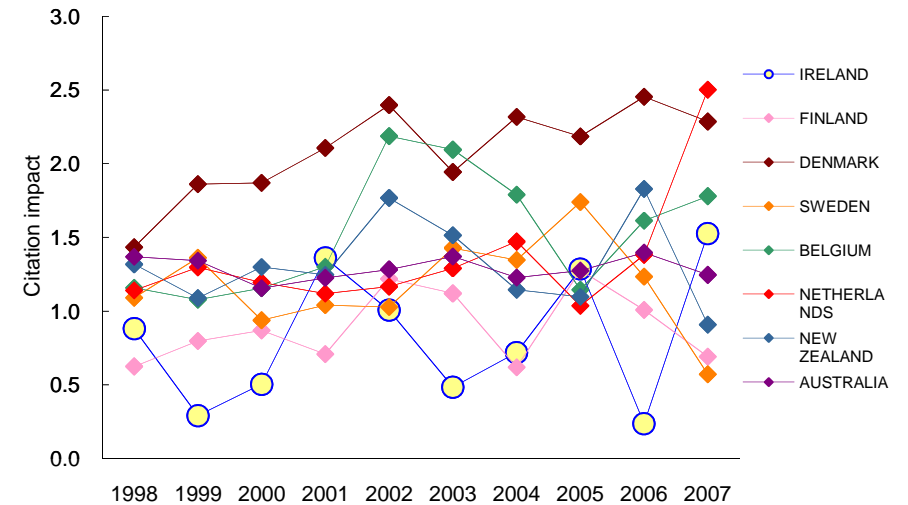
Data & analysis: Evidence, Thomson Reuters

Commentary

This analysis is presented for information but is based on very small number of publications (see Table 1.03.14). Civil engineering research outputs are disseminated in a number of different ways, and as a result a lot of good research will not necessarily be found in articles and reviews. Irish citation levels for civil engineering papers have generally been very low. Publications in 2001, 2005 and 2007 achieved on average citation rates above world average. Data from other years show citation rates well below world average.

The large variations in the chart can be attributed to the small number of papers produced, and diverse patterns of research dissemination, within civil engineering. Overall it can be seen that Irish publications have a poor citation performance in comparison with the other charted nations.

Table 1.07.15 Citation impact of electrical engineering, electronic engineering, information engineering papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland citation impact	0.92	1.19	0.97	-19%
Group average citation impact	1.05	1.13	1.17	+3%
Ireland / Group average	0.88	1.05	0.83	-21%
Ireland rank within Group	12	8	12	⇩
Ireland rank within charted nations	8	6	6	⇔

Data & analysis: Evidence, Thomson Reuters

Chart 1.07.15 Citation impact of electrical engineering, electronic engineering, information engineering papers
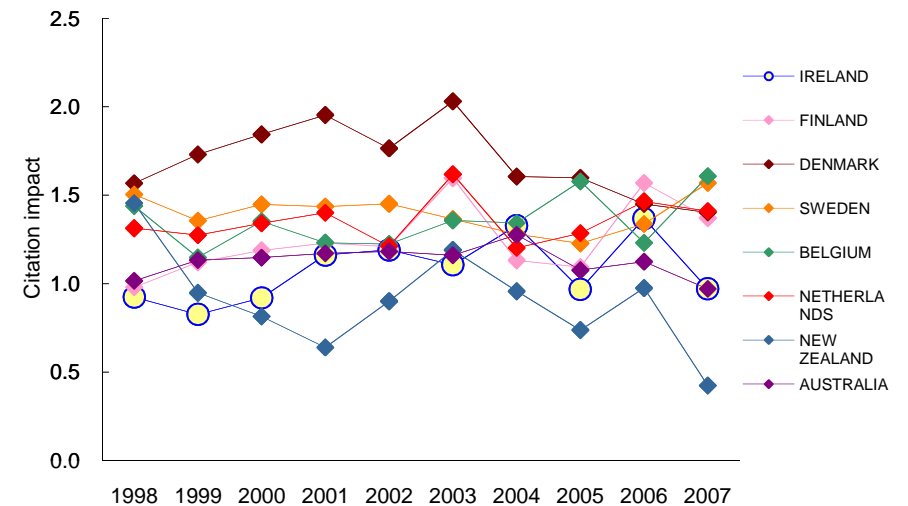
Data & analysis: Evidence, Thomson Reuters

Commentary

Citation rates for Irish electrical, electronic and information engineering papers are generally poor – below world average and towards the bottom of the rankings in terms of the comparator group of nations. In 2007 Irish citation rates were worse than all comparators with the exception of Australia, New Zealand and the Asian nations.

The chart shows that Ireland compares poorly with other charted nations over the ten year period 1998 – 2007 – the only exception to this being New Zealand where research in electrical, electronic and information engineering received even lower levels of citation.

Table 1.07.16 Citation impact of mechanical engineering papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland citation impact	0.80	1.35	1.64	+22%
Group average citation impact	1.06	1.15	1.19	+4%
Ireland / Group average	0.76	1.17	1.38	+17%
Ireland rank within Group	16	3	3	⇔
Ireland rank within charted nations	8	3	3	⇔

Data & analysis: Evidence, Thomson Reuters

Chart 1.07.16 Citation impact of mechanical engineering papers
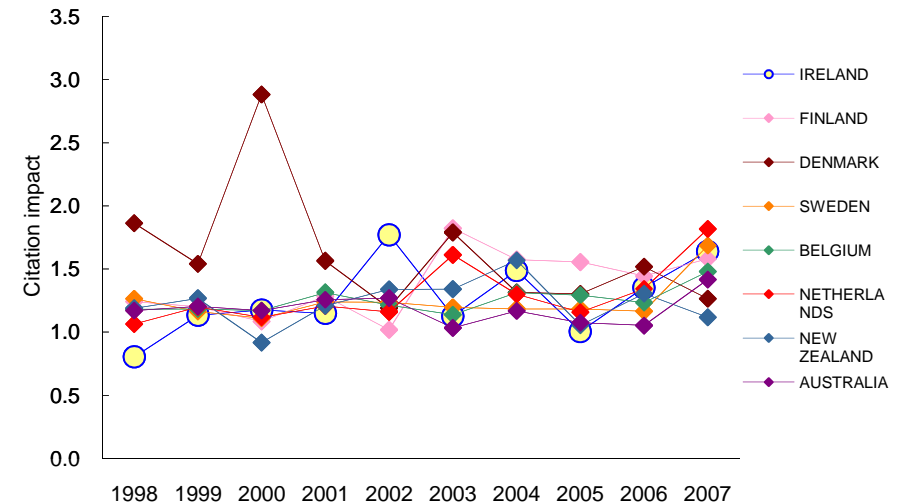
Data & analysis: Evidence, Thomson Reuters

Commentary

From a low citation rate in 1998, mechanical engineering research in Ireland has now reached the position where it is cited more frequently than research from any of the comparator countries with the exception of Finland and Denmark. This is a subject where volume of research has decreased (by 17% - see Indicator 1.31.16) while impact has increased.

The chart shows that Irish mechanical engineering papers have been cited more frequently than world average for most years between 1998 and 2007, with higher rates of citation in 2002, 2004 and 2007. In recent years Irish research has been ranked third within the charted group.

Table 1.07.17 Citation impact of social sciences papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland citation impact	0.77	0.82	1.23	+51%
Group average citation impact	0.86	0.94	0.93	-1%
Ireland / Group average	0.90	0.87	1.33	+53%
Ireland rank within Group	14	14	4	⇧
Ireland rank within charted nations	7	8	3	⇧

Data & analysis: Evidence, Thomson Reuters

Chart 1.07.17 Citation impact of social sciences papers
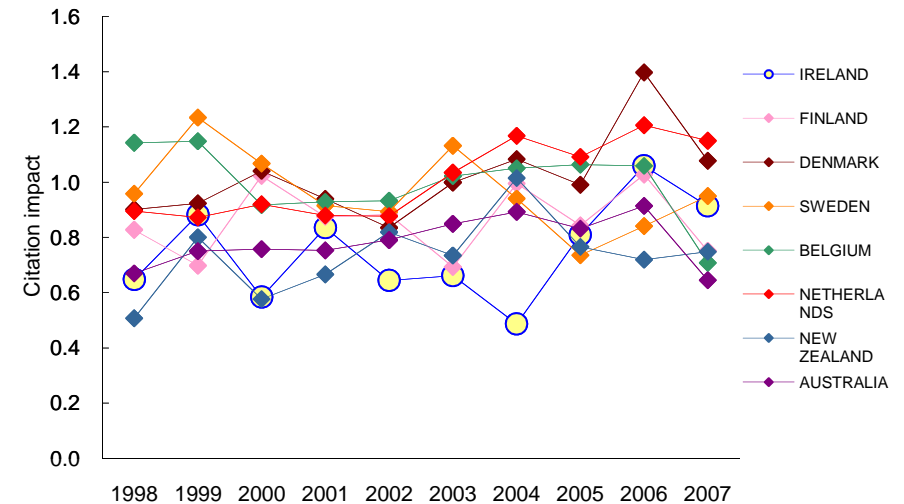
Data & analysis: Evidence, Thomson Reuters

Commentary

Indexed journal articles in social science research are dominated by the USA and UK, where large and active communities extensively co-cite and hence elevate the world average. Comparative citation rates for Irish social science research are well below that world average for publications produced each year since 1998, with the exception of 2005 and 2007. Average citation rates for other members of the comparator group are also low, but even so Ireland only achieves a ranking of 14th out of the 19 nations for the five year period 2002-2006.

The chart illustrates the way in which citation rates for Irish Social sciences have generally been lower than citation rates achieved by social science research from the other charted nations. Irish papers published in 2007 were cited more frequently (citation impact = 1.23), lifting Ireland up into the middle ranks of the charted nations.

Table 1.07.18 Citation impact of economics and business papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland citation impact	0.65	0.73	0.91	+25%
Group average citation impact	0.76	0.87	0.89	+3%
Ireland / Group average	0.85	0.85	1.03	+22%
Ireland rank within Group	13	14	8	⇧
Ireland rank within charted nations	7	8	4	⇧

Data & analysis: Evidence, Thomson Reuters

Chart 1.07.18 Citation impact of economics and business papers
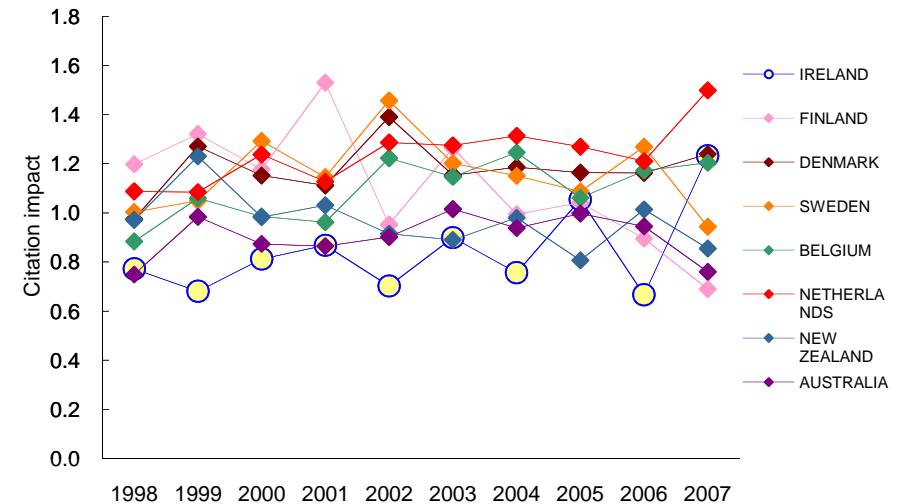
Data & analysis: Evidence, Thomson Reuters

Commentary

Business research is dominated by exceptional activity and a distinctive publishing and citation culture in the USA. Irish economics and business research improved in terms of rates of citation in the period 2005 – 2007. Overall performance is weak relative to the USA-centric world average. Publications for all years over the period 1998 – 2007 (with the exception of 2006) achieved average citation rates which were lower than world average. Ireland's ranking within the comparator group has moved up to 8th, but this position reflects other poor performances relative to world average by a number of comparator nations rather than any great strength in Irish research.

The chart shows variable rates of citation for Irish economics and business papers over the ten year period 1998 – 2007, with a comparatively good showing in 2006 and 2007. The baseline for Ireland and the other charted nations is very low.

Table 1.07.19 Citation impact of psychology papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland citation impact	0.40	0.81	1.86	+130%
Group average citation impact	0.88	0.86	1.02	+18%
Ireland / Group average	0.46	0.94	1.83	+94%
Ireland rank within Group	19	12	2	⇧
Ireland rank within charted nations	8	8	1	⇧

Data & analysis: Evidence, Thomson Reuters

Chart 1.07.19 Citation impact of psychology papers
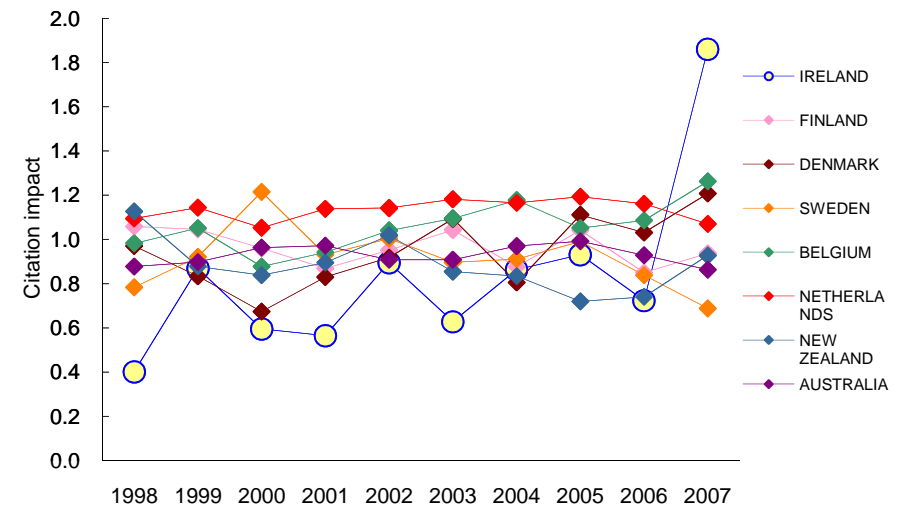
Data & analysis: Evidence, Thomson Reuters

Commentary

The headline figure for citation impact in this table, taken together with the increase in research volume (see table 1.03.19) suggests that 2007 was an extremely good year for psychology research in Ireland. These data need to be interpreted with some scepticism firstly as the total volume of psychology research is quite low, secondly in case this is just a one-year peak in performance and thirdly as this good year needs to be seen in the context of generally very weak citation performance both by Ireland and its comparator nations.

The overall trend shows an improvement in the rate of citation of Irish psychology papers. Note however that for every year except 2007 citation rates were less than world average. Performance by other charted nations is more static, and it will be interesting to see whether Irish publications in subsequent years maintain this high level of citation impact.

Table 1.07.20 Citation impact of humanities papers

	Original value (1998)	Recent average (2002-2006)	Current value (2007)	Current relative to Recent
Ireland citation impact	0.22	0.77	0.41	-47%
Group average citation impact	1.02	1.03	0.84	-19%
Ireland / Group average	0.22	0.75	0.49	-35%
Ireland rank within Group	19	15	15	⇔
Ireland rank within charted nations	8	8	6	⇧

Data & analysis: Evidence, Thomson Reuters

Chart 1.07.20 Citation impact of humanities papers
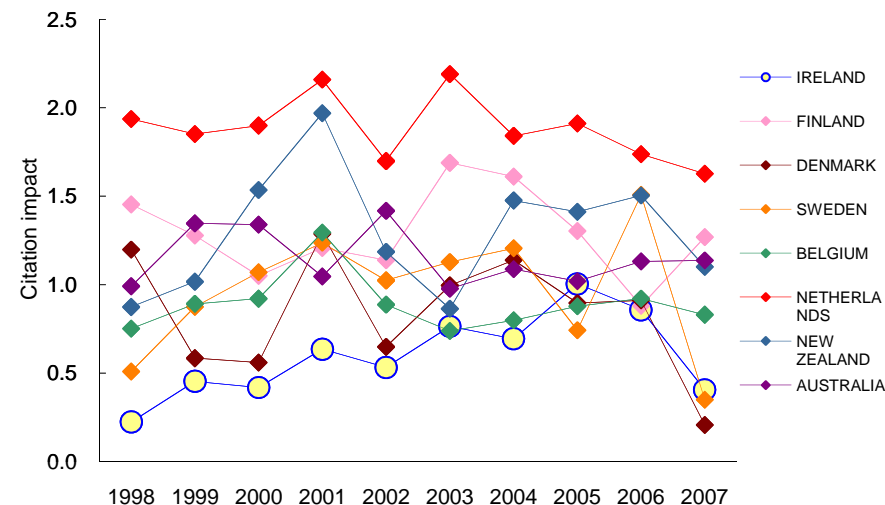
Data & analysis: Evidence, Thomson Reuters

Commentary

Irish humanities research is generally cited at a low level relative to world average. Ireland is 15th in the rankings for citation impact, better only than Brazil, India and Singapore (countries with poor performance in these disciplines). These results need to be interpreted with care, however, as the total volume of Irish humanities research is fairly low, and research dissemination in the humanities often focuses on books and monographs rather than research papers.

The chart shows a relatively weak citation impact for Irish humanities research over the ten year period 1998 – 2007. Ireland is at the bottom of the rankings in nearly every year. The best performance in 2005 just achieved a citation impact of 1.0, equal to the world average.

2.01   Number of Irish HE sector papers

**Table 2.01 Number of papers in all research fields**

	5-year total, 1998-2002	5-year total, 2003-2007	change
University College Dublin (UCD)	2861	4510	36.6%
Trinity College Dublin (TCD)	2553	3904	34.6%
University College Cork (UCC)	2158	3217	32.9%
NUI Galway (NUIG)	1065	1692	37.1%
Dublin City University (DCU)	783	1345	41.8%
University of Limerick (UL)	524	1125	53.4%
NUI Maynooth (NUIM)	430	842	48.9%
Royal College of Surgeons in Ireland (RCSI)	429	655	34.5%
Dublin IT (DIT)	284	495	42.6%
Dublin Institute for Advanced Studies (DIAS)	225	343	34.4%
Other Irish HE institutions	296	561	47.2%
Queens University Belfast (QUB)	4531	5370	15.6%
University of Ulster (UU)	1630	2136	23.7%

Data & analysis: Evidence, Thomson Reuters

Chart 2.01 Number of papers in all research fields

Data & analysis: Evidence, Thomson Reuters

Commentary

The output of the Irish HEIs has increased consistently over the decade. This is reflected in an increase of around 40%, or even more, of their indexed output volume in the most recent 5-year period compared to the previous five years. For some institutions this means a near-doubling over the ten years as a whole. Growth rates are somewhat less for the largest institutions, because they are already relatively productive so a further increase may be more challenging. It appears that three institutions (UCD; TCD; UCC) have pulled ahead of the rest, but in fact theirs are not the highest growth rates. UL and NUIM have more rapid growth but remain relatively small.
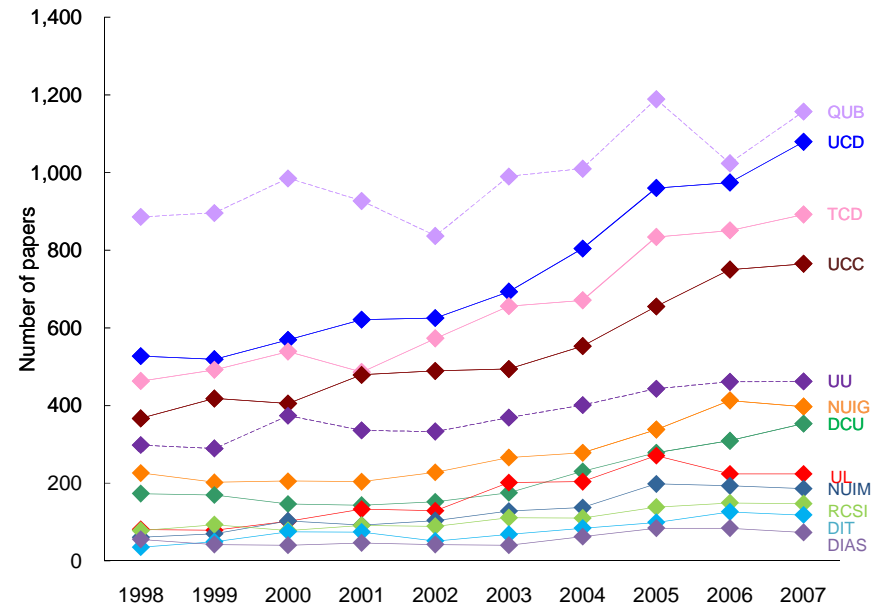
The Chart confirms the impression that the HE institutions in Ireland have steadily gained on those in Northern Ireland. Whereas QUB had a clear lead it now forms part of a lead group with the three largest HEIs in the Republic. UCD has increasingly more total outputs than TCD. UU now sits in a second group with NUIG and DCU and these are somewhat ahead of the other institutions which then form a third grouping. The profile for UL is the only one with irregular growth, having risen and then fallen back. The various institutional profiles will, of course, be dependent on underlying subject portfolios and growth opportunities related to those.

Table 2.02.01 Number of clinical papers

	5-year total, 1998-2002	5-year total, 2003-2007	change
University College Dublin (UCD)	510	877	41.8%
Trinity College Dublin (TCD)	348	597	41.7%
University College Cork (UCC)	256	359	28.7%
NUI Galway (NUIG)	95	187	49.2%
Dublin City University (DCU)	37	94	60.6%
University of Limerick (UL)	18	46	60.9%
NUI Maynooth (NUIM)	52	68	23.5%
Royal College of Surgeons in Ireland (RCSI)	185	271	31.7%
Dublin IT (DIT)	42	50	16.0%
Dublin Institute for Advanced Studies (DIAS)	data too sparse to index		
Other Irish HE institutions	9	29	69.0%
Queens University Belfast (QUB)	784	855	8.3%
University of Ulster (UU)	178	283	37.1%

Data & analysis: Evidence, Thomson Reuters

Chart 2.02.01 Number of clinical papers
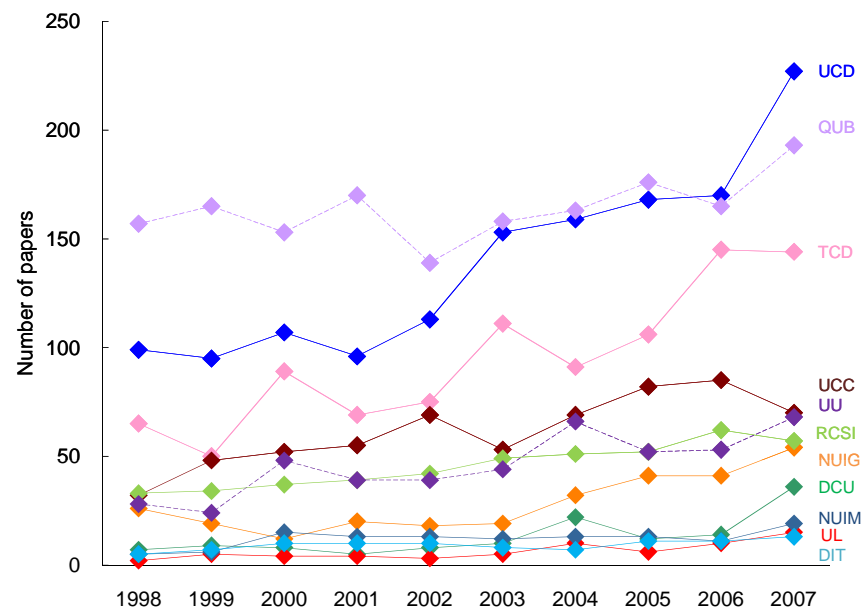
Data & analysis: Evidence, Thomson Reuters

Commentary

Growth of clinical research publications is very marked for almost every institution. Both UCD and TCD show a 40% increase between early and late periods. Both now similar in output volume to QUB. UCC has grown less, whereas smaller institutions have expanded from lower base. RCSI has good growth, though not exceptional compared to others, from a relatively large base associated with its niche role.

The difference in volume between the largest and the other institutions affirms the role of key medical schools in clinical research; this difference would be seen in other national systems. The rise in clinical output seems most marked after 2001. Growth at NUIG is also more evident in the graph and it can be seen to have caught RCSI on annual data. UCC output appears to plateau and fall back.

Table 2.02.02 Number of health & medically-related papers

	5-year total, 1998-2002	5-year total, 2003-2007	change
University College Dublin (UCD)	346	495	30.1%
Trinity College Dublin (TCD)	435	681	36.1%
University College Cork (UCC)	111	258	57.0%
NUI Galway (NUIG)	147	228	35.5%
Dublin City University (DCU)	22	54	59.3%
University of Limerick (UL)	26	80	67.5%
NUI Maynooth (NUIM)	24	70	65.7%
Royal College of Surgeons in Ireland (RCSI)	163	235	30.6%
Dublin IT (DIT)	44	49	10.2%
Dublin Institute for Advanced Studies (DIAS)	data too sparse to index		
Other Irish HE institutions	16	69	76.8%
Queens University Belfast (QUB)	606	702	13.7%
University of Ulster (UU)	376	516	27.1%

Data & analysis: Evidence, Thomson Reuters

Chart 2.02.02 Number of health & medically-related papers
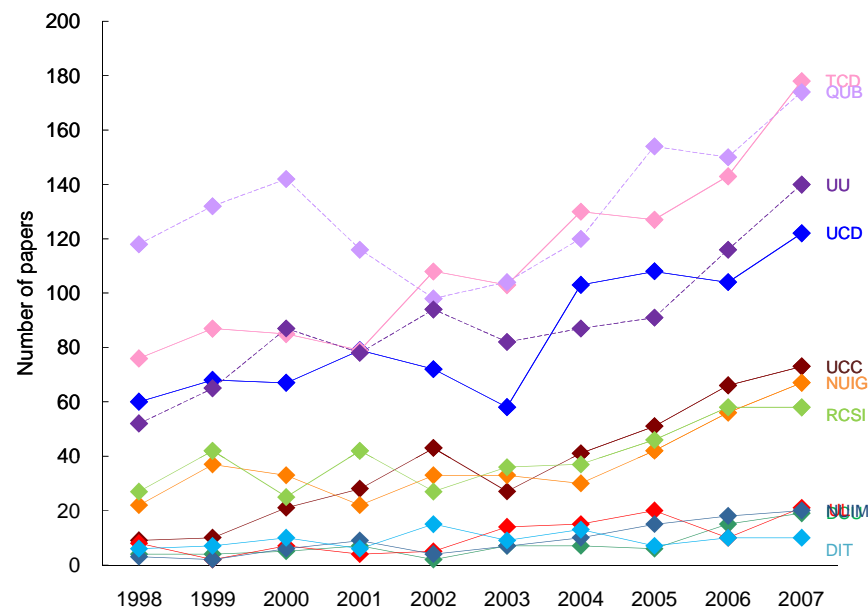
Data & analysis: Evidence, Thomson Reuters

Commentary

Health research is a growth area for many countries. Irish institutions have reflected this expansion but a 30% volume increase between early and late periods is in line with overall growth. Note that in absolute terms TCD has more output here than in clinical research while UCD has much less. Growth is above institutional average for UCC and some smaller HEIs including DCU, UL and NUIM. In Northern Ireland, there is strong growth at UU but this is less so for QUB.

The graph shows broadly three groups, led by TCD and QUB with UU and UCD. QUB's recent growth is offset by some contraction in the early period. A second group is led by UCC with the RCSI and NUIG. Other institutions have much smaller annual volumes.

Table 2.02.03 Number of biological sciences papers

	5-year total, 1998-2002	5-year total, 2003-2007	change
University College Dublin (UCD)	981	1423	31.1%
Trinity College Dublin (TCD)	585	754	22.4%
University College Cork (UCC)	943	1152	18.1%
NUI Galway (NUIG)	260	388	33.0%
Dublin City University (DCU)	138	179	22.9%
University of Limerick (UL)	95	149	36.2%
NUI Maynooth (NUIM)	76	173	56.1%
Royal College of Surgeons in Ireland (RCSI)	70	144	51.4%
Dublin IT (DIT)	52	102	49.0%
Dublin Institute for Advanced Studies (DIAS)	data too sparse to index		
Other Irish HE institutions	93	165	43.6%
Queens University Belfast (QUB)	828	1062	22.0%
University of Ulster (UU)	357	469	23.9%

Data & analysis: Evidence, Thomson Reuters

Chart 2.02.03 Number of biological sciences papers
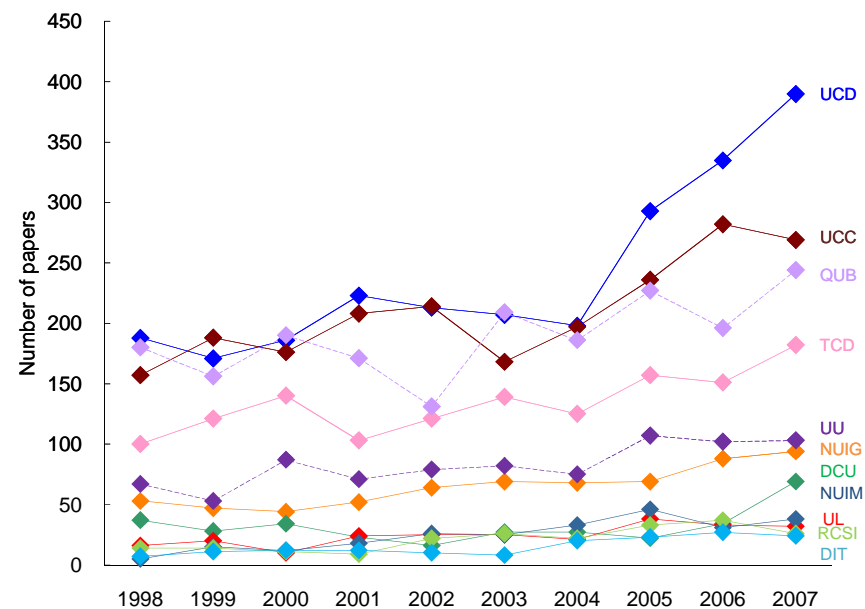
Data & analysis: Evidence, Thomson Reuters

Commentary

Biological sciences are very active areas internationally, and there is therefore an intense competition to publish. This is an area of significant relative volume and growth for UCD, whereas growth is less marked for TCD. This is also an area where there is exceptional relative volume for UCC, though less relative growth, but it nonetheless has greater output than QUB and TCD. Growth is relatively greater at NUIG, as at some of the smaller institutions, in line with the pattern of expansion at that HEI. NUIM and RCSI both double their output between the first and second five-year periods

The extent to which UCD has moved ahead in terms of output, almost doubling its publication volume, is clear in the graph, which also shows UCC consolidating a lead on QUB. TCD has maintained a steady growth. NUIG has roughly maintained its volume position relative to UU.

Table 2.02.04 Number of environment papers

	5-year total, 1998-2002	5-year total, 2003-2007	change
University College Dublin (UCD)	196	326	39.9%
Trinity College Dublin (TCD)	120	221	45.7%
University College Cork (UCC)	217	269	19.3%
NUI Galway (NUIG)	193	296	34.8%
Dublin City University (DCU)	8	27	70.4%
University of Limerick (UL)	18	46	60.9%
NUI Maynooth (NUIM)	13	42	69.0%
Royal College of Surgeons in Ireland (RCSI)	data too sparse to index		
Dublin IT (DIT)	14	27	48.1%
Dublin Institute for Advanced Studies (DIAS)	15	48	68.8%
Other Irish HE institutions	31	77	59.7%
Queens University Belfast (QUB)	373	458	18.6%
University of Ulster (UU)	152	155	1.9%

Data & analysis: Evidence, Thomson Reuters

Chart 2.02.04 Number of environment papers
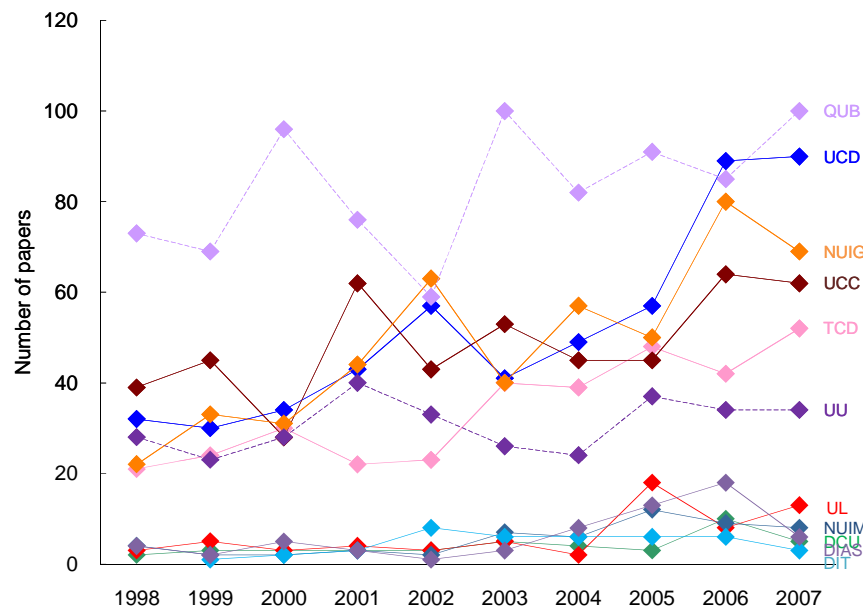
Data & analysis: Evidence, Thomson Reuters

Commentary

While the volume of environmental research is less than other sciences, this is an important policy area with much innovative research globally and hence typically rapid growth. There are four major players for Ireland, with a balance of activity across these. NUIG has particular capacity here but its growth between the early and late five-year periods is less than most other HEIs, except UCC.

The growth profile of the major Ireland HEIs is evident in the chart. UCD seems now to be consistently the larger and has similar volume to QUB. Both QUB and UU have little overall growth over the decade. TCD and UCC seem on this analysis to have grown less than the other two, while the significance of this field for NUIG is very clear. The smaller institutions have not developed a significant capacity.

Table 2.02.05 Number of mathematics papers

	5-year total, 1998-2002	5-year total, 2003-2007	change
University College Dublin (UCD)	151	182	17.0%
Trinity College Dublin (TCD)	73	173	57.8%
University College Cork (UCC)	109	171	36.3%
NUI Galway (NUIG)	207	251	17.5%
Dublin City University (DCU)	39	91	57.1%
University of Limerick (UL)	35	76	53.9%
NUI Maynooth (NUIM)	66	98	32.7%
Royal College of Surgeons in Ireland (RCSI)	data too sparse to index		
Dublin IT (DIT)	17	40	57.5%
Dublin Institute for Advanced Studies (DIAS)	43	49	12.2%
Other Irish HE institutions	17	15	-13.3%
Queens University Belfast (QUB)	135	193	30.1%
University of Ulster (UU)	49	69	29.0%

Data & analysis: Evidence, Thomson Reuters

Chart 2.02.05 Number of mathematics papers
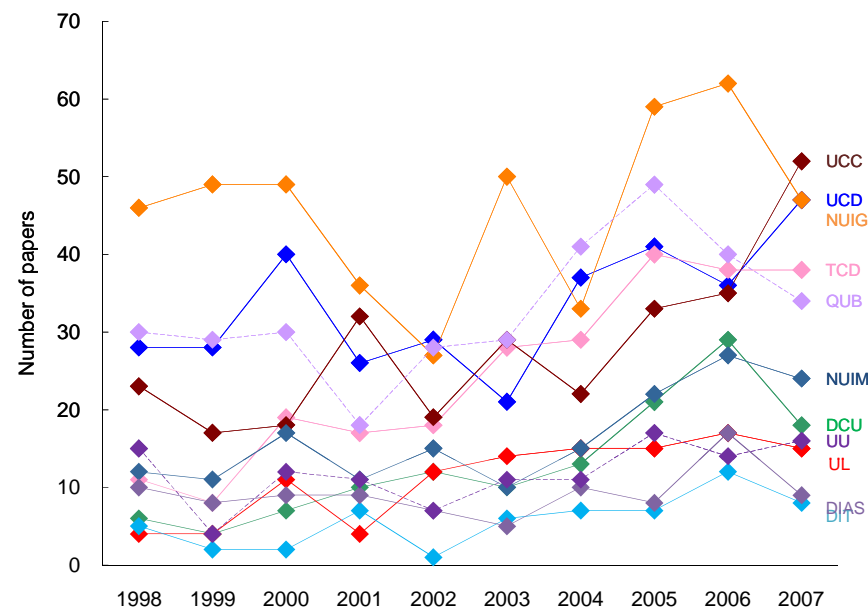
Data & analysis: Evidence, Thomson Reuters

Commentary

Mathematics research volumes are not large and vary erratically from year to year for many HEIs world-wide. TCD has a substantial growth between early and late periods while UCD has lower growth than its average. NUIG has the largest volume of research, and has expanded less than the other large institutions which are now similar in volume. They are also similar in volume to Northern Ireland HEIs, where QUB has much greater growth than is typical.

The graph reflects the recent growth and separation of the largest HEIs, although it also reveals a somewhat exceptional curve down and up for NUIG. A number of the smaller institutions appear to have grown synchronously to 2006 and then fallen back in 2007, which may reflect a common factor.

Table 2.02.06 Number of physical sciences papers

	5-year total, 1998-2002	5-year total, 2003-2007	change	
University College Dublin (UCD)	522	879		40.6%
Trinity College Dublin (TCD)	799	1213		34.1%
University College Cork (UCC)	522	935		44.2%
NUI Galway (NUIG)	193	293		34.1%
Dublin City University (DCU)	479	708		32.3%
University of Limerick (UL)	204	421		51.5%
NUI Maynooth (NUIM)	141	239		41.0%
Royal College of Surgeons in Ireland (RCSI)	25	59		57.6%
Dublin IT (DIT)	129	240		46.3%
Dublin Institute for Advanced Studies (DIAS)	172	265		35.1%
Other Irish HE institutions	115	184		37.5%
Queens University Belfast	1473	1687		12.7%
University of Ulster (UU)	202	290		30.3%

Data & analysis: Evidence, Thomson Reuters

Chart 2.02.06 Number of physical sciences papers
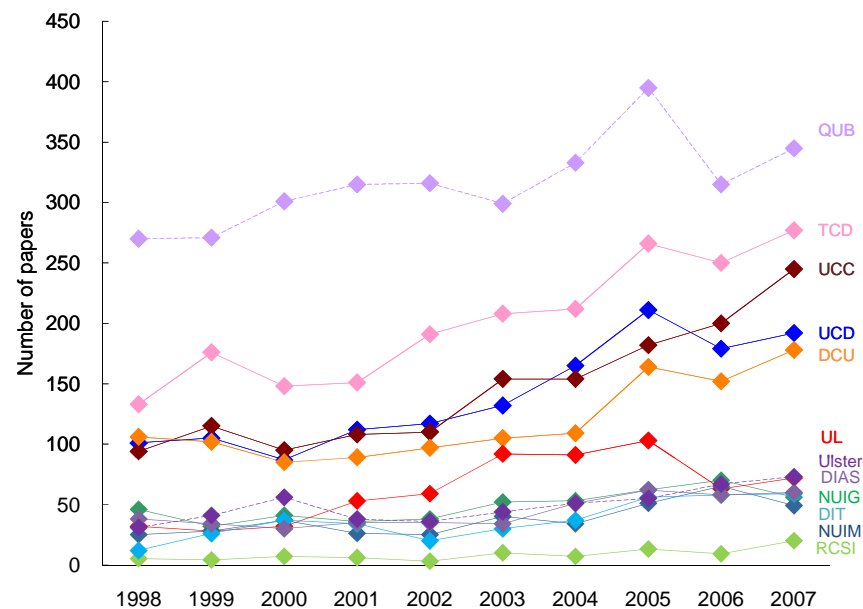
Data & analysis: Evidence, Thomson Reuters

Commentary

Physical sciences require substantial, well-established facilities and are often dominated by larger and older institutions, so the relative volume for DCU and DIAS is notable. QUB, and the four larger Ireland HEIs, are distinctly separated from other institutions, including UL, UU and NUIG. With the exception of QUB, which has changed little between early and late periods, the others all exhibit marked growth, rather ahead of their institutional averages. Note that the output for DIAS in this area is more than half its total volume

The graph confirms the consistent upward trends for the larger HEIs, but shows that while UL was tracking DCU it has now fallen well back. DCU itself has not shown the same growth as some HEIs of a similar size at the start of the period. But is not very different in current volume to UCD, which UCC has now passed and is now approaching TCD in capacity. QUB's 'growth' seen in the table is evidently dependent on a peak year in 2005.

Table 2.02.07 Number of engineering papers

	5-year total, 1998-2002	5-year total, 2003-2007	change
University College Dublin (UCD)	344	713	51.8%
Trinity College Dublin (TCD)	335	632	47.0%
University College Cork (UCC)	322	641	49.8%
NUI Galway (NUIG)	143	318	55.0%
Dublin City University (DCU)	220	457	51.9%
University of Limerick (UL)	217	521	58.3%
NUI Maynooth (NUIM)	32	190	83.2%
Royal College of Surgeons in Ireland (RCSI)	data too sparse to index		
Dublin IT (DIT)	45	125	64.0%
Dublin Institute for Advanced Studies (DIAS)	data too sparse to index		
Other Irish HE institutions	67	116	42.2%
Queens University Belfast (QUB)	566	935	39.5%
University of Ulster (UU)	300	469	36.0%

Data & analysis: Evidence, Thomson Reuters

Chart 2.02.07 Number of engineering papers
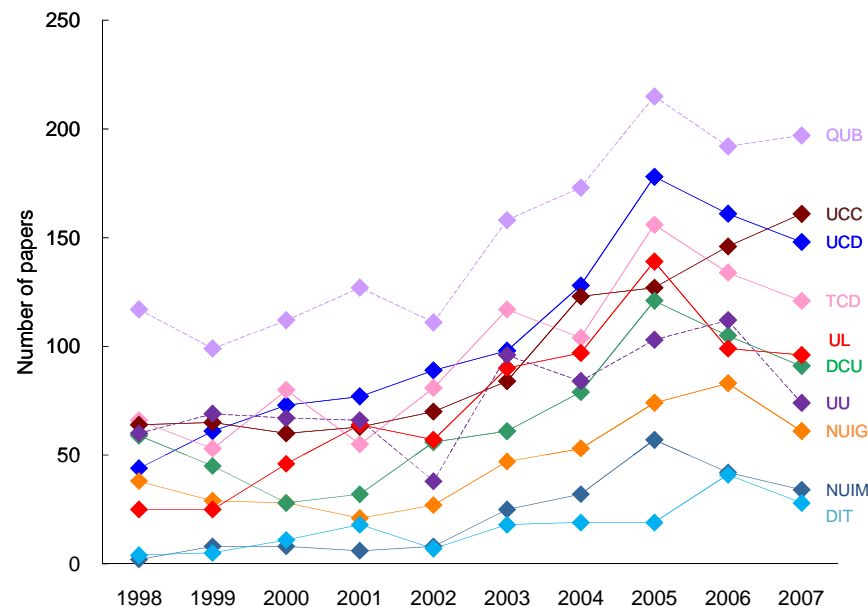
Data & analysis: Evidence, Thomson Reuters

Commentary

Engineering's leading research outputs combine both journal articles and conference proceedings, but the latter are not analysed here. For most Ireland HEIs there is a marked increase in output, above the institutional average, with around twice the volume for the later period compared with the earlier five-years. This is seen in Northern Ireland as well, and is partly a reflection of a global shift in publishing patterns. The balance across HEIs is similar to the overall balance in volume, except in the case of UL for which this is a key area accounting for about half its recent output.

The graph shows a distinct common pattern, with steep rises to 2005 and then a recent decline, with the exception of UCC and QUB. While the UCC pattern needs investigation, QUB gives the clue to the pattern which is driven by external factors. The approach to the UK's RAE2008 will have driven up engineering contributions to journals rather than conference and have locally increased competition in Anglophone journals.

2.02.08 Number of Irish HE sector papers in 10 main research areas

Table 2.02.08 Number of social science papers

	5-year total, 1998-2002	5-year total, 2003-2007	change
University College Dublin (UCD)	184	246	25.2%
Trinity College Dublin (TCD)	146	184	20.7%
University College Cork (UCC)	101	84	-20.2%
NUI Galway (NUIG)	52	87	40.2%
Dublin City University (DCU)	15	56	73.2%
University of Limerick (UL)	38	65	41.5%
NUI Maynooth (NUIM)	55	54	-1.9%
Royal College of Surgeons in Ireland (RCSI)	33	21	-57.1%
Dublin IT (DIT)	data too sparse to index		
Dublin Institute for Advanced Studies (DIAS)	data too sparse to index		
Other Irish HE institutions	3	21	85.7%
Queens University Belfast (QUB)	288	307	6.2%
University of Ulster (UU)	233	258	9.7%

Data & analysis: Evidence, Thomson Reuters

Chart 2.02.08 Number of social science papers
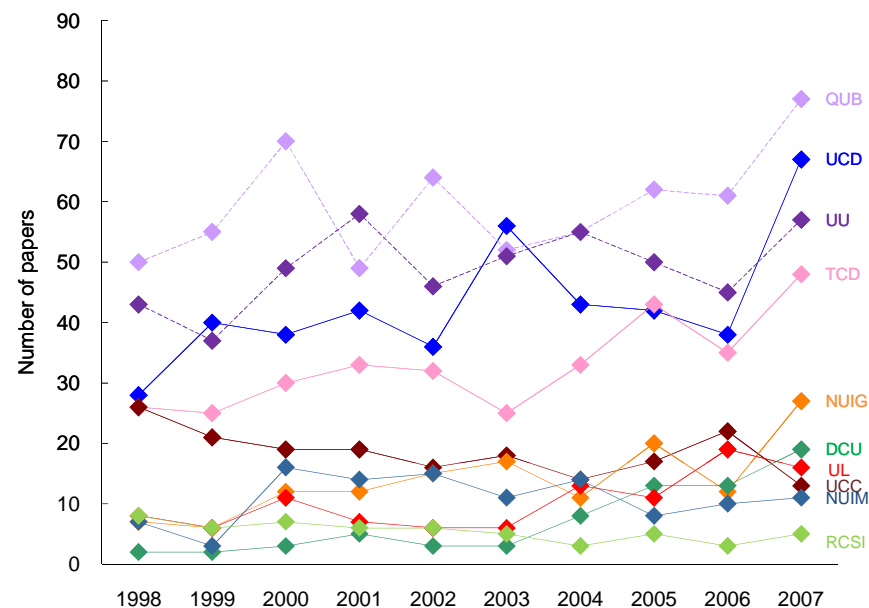
Data & analysis: Evidence, Thomson Reuters

Commentary

Social science research is a broad portfolio of activity, where much good output appears in reports rather than journals. However, a US paradigm of more journal-based research has been growing in Europe. For Ireland, output is clearly dominated by UCD and TCD but both the Northern Ireland HEIs have a larger output and the Irish HEIs have lower growth than is their norm. Some, such as UCC, have declined in output. This should therefore be regarded as an area for future growth and, perhaps, cultural change for Ireland.

There is a change in publishing culture across Europe, which is affecting social sciences and humanities. The use of journal literature is becoming much more widespread as a primary mode for disseminating new research outcomes. The graph shows both the growth for the larger Dublin HEIs and their move to close on the Northern Ireland HEIs. The general trend in the smaller institutions is less evident because the growth is on a small base and is difficult to discern.
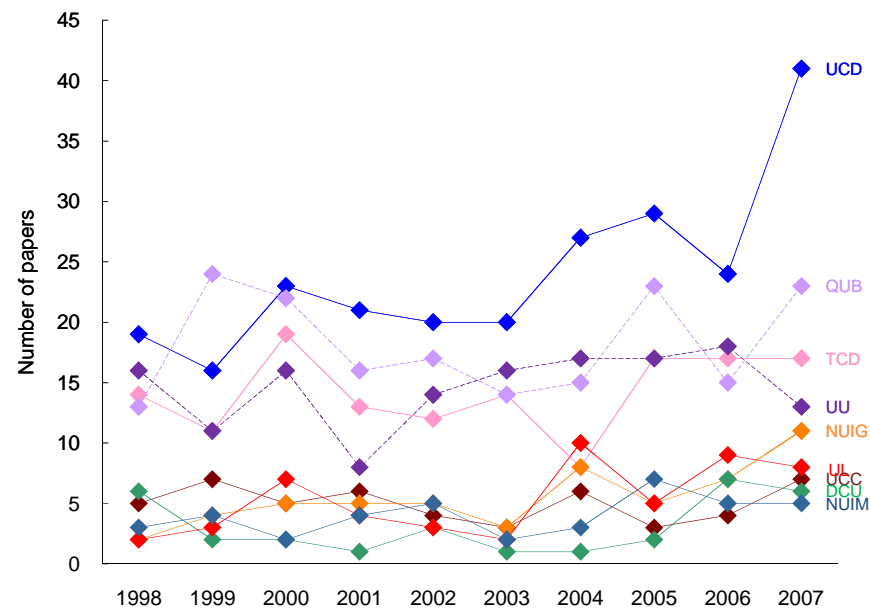
Table 2.02.09 Number of business papers

Chart 2.02.09 Number of business papers

	5-year total, 1998-2002	5-year total, 2003-2007	change
University College Dublin (UCD)	99	141	29.8%
Trinity College Dublin (TCD)	69	73	5.5%
University College Cork (UCC)	27	23	-17.4%
NUI Galway (NUIG)	21	34	38.2%
Dublin City University (DCU)	14	17	17.6%
University of Limerick (UL)	19	34	44.1%
NUI Maynooth (NUIM)	18	22	18.2%
Royal College of Surgeons in Ireland (RCSI)	data too sparse to index		
Dublin IT (DIT)	data too sparse to index		
Dublin Institute for Advanced Studies (DIAS)	data too sparse to index		
Other Irish HE institutions	8	9	11.1%
Queens University Belfast (QUB)	92	90	-2.2%
University of Ulster (UU)	65	81	19.8%

Data & analysis: Evidence, Thomson Reuters

Data & analysis: Evidence, Thomson Reuters

Commentary

Business Schools across Europe have become increasingly research active and publication orientated. Although growth rates are generally low for Ireland in this area, UCD has clearly affirmed its lead on output. Some synchronicity with QUB suggests a possible link in activity. UU and TCD are relatively significant publishers while other institutions have relatively little output

There is a change in publishing culture across Europe, which is affecting social sciences, including business, and the humanities. The use of journal literature is becoming much more widespread as a primary mode for disseminating new research outcomes. Business output volume is still very low, with most institutions producing barely a handful of papers per year. TCD is not increasing its output, so the growth at UCD marks it out as the centre for business research rather than just a leader in a more general growth pattern.

2.02.10 Number of Irish HE sector papers in 10 main research areas

**Table 2.02.10 Number of arts and humanities papers**

	5-year total, 1998-2002	5-year total, 2003-2007	change
University College Dublin (UCD)	157	180	12.8%
Trinity College Dublin (TCD)	133	171	22.2%
University College Cork (UCC)	81	83	2.4%
NUI Galway (NUIG)	42	57	26.3%
Dublin City University (DCU)	27	43	37.2%
University of Limerick (UL)	10	59	83.1%
NUI Maynooth (NUIM)	28	43	34.9%
Royal College of Surgeons in Ireland (RCSI)	data too sparse to index		
Dublin IT (DIT)	data too sparse to index		
Dublin Institute for Advanced Studies (DIAS)	data too sparse to index		
Other Irish HE institutions	32	44	27.3%
Queens University Belfast (QUB)	210	224	6.3%
University of Ulster (UU)	129	147	12.2%

Data & analysis: Evidence, Thomson Reuters

Chart 2.02.10 Number of arts and humanities papers

Data & analysis: Evidence, Thomson Reuters

Commentary

Volume of output is broadly in line with overall institutional patterns. These data are included for information only and should not be regarded as an important performance indicator because the publication pattern in arts and humanities uses a much wider range of modes, including books and non-print media.
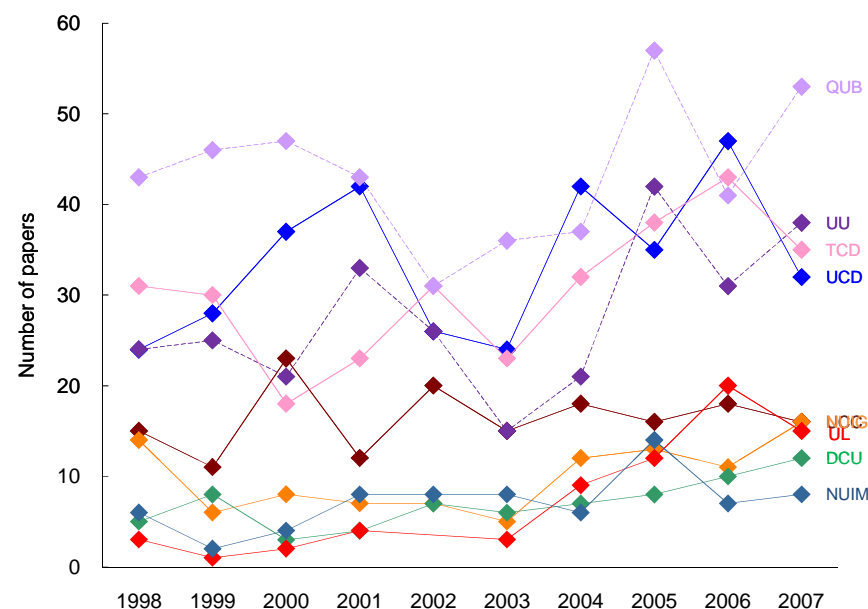
There is a change in publishing culture across Europe, which is affecting the arts and humanities, as well as the social sciences. The use of journal literature is becoming much more widespread as a primary mode for disseminating new research outcomes. However, many of these fields will continue to use the learned monograph as the most prestigious output mode for the foreseeable future.

Table 2.03.01 Number of biological sciences: Organismal biology papers

	5-year total, 1998-2002	5-year total, 2003-2007	change
University College Dublin (UCD)	218	319	31.7%
Trinity College Dublin (TCD)	138	226	38.9%
University College Cork (UCC)	229	274	16.4%
NUI Galway (NUIG)	116	165	29.7%
Dublin City University (DCU)	14	13	-7.7%
University of Limerick (UL)	9	19	52.6%
NUI Maynooth (NUIM)	28	83	66.3%
Royal College of Surgeons in Ireland (RCSI)	10	13	23.1%
Dublin IT (DIT)	21	31	32.3%
Dublin Institute for Advanced Studies (DIAS)	data too sparse to index		
data for other Irish HE institutions not analysed			
Queens University Belfast (QUB)	254	342	25.7%
University of Ulster (UU)	39	83	53.0%

Data & analysis: Evidence, Thomson Reuters

Chart 2.03.01 Number of biological sciences: Organismal biology papers
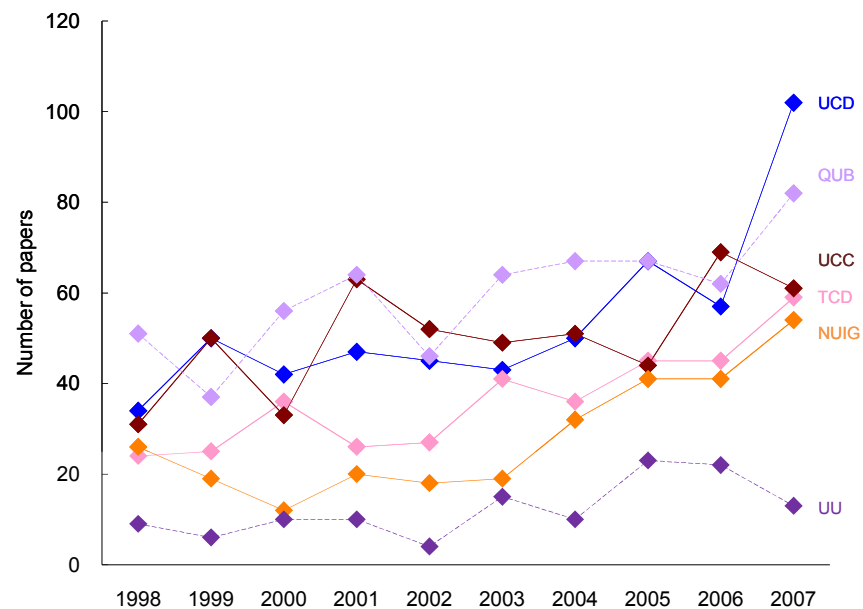
Data & analysis: Evidence, Thomson Reuters

Commentary

In organismal biology, four HEIs have significant volumes of activity and three of those (UCD, TCD and NUIG) have substantial increases of around one-third of their earlier volume into the later period. Despite being the second largest, UCC grows by a smaller percentage and this is also small compared to its growth in molecular and cellular biology. UCC is of a similar volume to QUB across the period and grows at a similar rate.

The chart indicates the extent to which the larger institutions have generally grown. UCD has more than kept pace with QUB over the period while also overtaking UCC. NUIG has moved well ahead of UU and is now of similar volume to TCD.

Table 2.03.02 Number of biological sciences: Molecular & cellular biology papers

	5-year total, 1998-2002	5-year total, 2003-2007	change
University College Dublin (UCD)	347	530	34.5%
Trinity College Dublin (TCD)	348	517	32.7%
University College Cork (UCC)	311	463	32.8%
NUI Galway (NUIG)	131	223	41.3%
Dublin City University (DCU)	79	122	35.2%
University of Limerick (UL)	23	57	59.6%
NUI Maynooth (NUIM)	40	119	66.4%
Royal College of Surgeons in Ireland (RCSI)	65	135	51.9%
Dublin IT (DIT)	24	47	48.9%
Dublin Institute for Advanced Studies (DIAS)	data too sparse to index		
data for other Irish HE institutions not analysed			
Queens University Belfast (QUB)	390	480	18.8%
University of Ulster (UU)	157	241	34.9%

Data & analysis: Evidence, Thomson Reuters

Chart 2.03.02 Number of biological sciences: Molecular & cellular biology papers

Data & analysis: Evidence, Thomson Reuters

Commentary

Molecular biology is one of the most intensively funded and competitive research areas globally. All the Irish institutions have expanded significantly between the early and late periods. In Northern Ireland QUB has grown but by a lesser volume while UU's growth is in line with the larger Irish HEIs. Among the smaller institutions, the near doubling of volume for RCSI is notable.
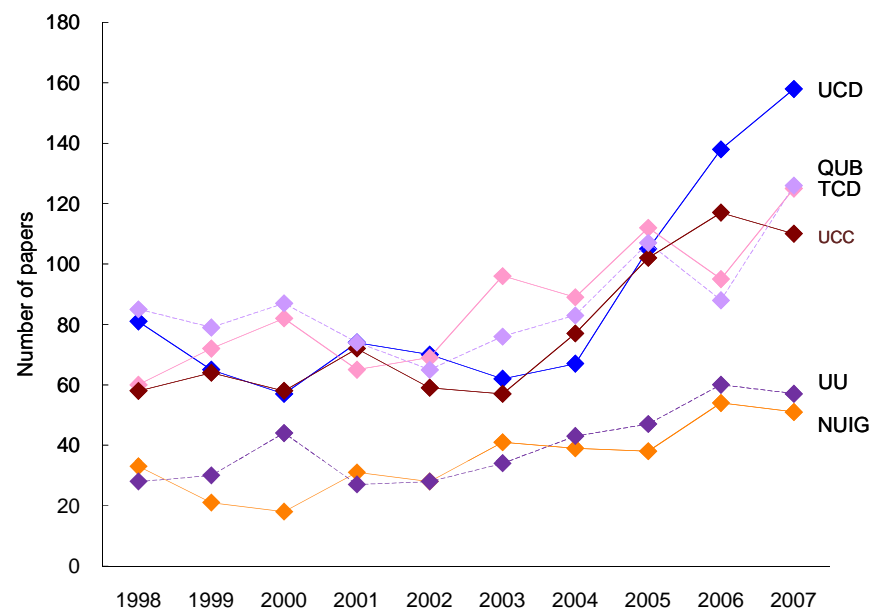
The chart shows the larger institutions moving ahead of NUIG, where biological strength is in organismal areas, and UU. UCD is now somewhat ahead of the others, while TCD and QUB roughly keep pace. UCC has been on a trajectory to overtake these but plateaued.

Table 2.03.03 Number of physics and materials sciences papers

	5-year total, 1998-2002	5-year total, 2003-2007	change
University College Dublin (UCD)	273	482	43.4%
Trinity College Dublin (TCD)	614	937	34.5%
University College Cork (UCC)	278	614	54.7%
NUI Galway (NUIG)	84	154	45.5%
Dublin City University (DCU)	241	406	40.6%
University of Limerick (UL)	128	308	58.4%
NUI Maynooth (NUIM)	115	191	39.8%
Royal College of Surgeons in Ireland (RCSI)	data too sparse to index		
Dublin IT (DIT)	77	129	40.3%
Dublin Institute for Advanced Studies (DIAS)	167	264	36.7%
data for other Irish HE institutions not analysed			
Queens University Belfast (QUB)	979	1166	16.0%
University of Ulster (UU)	107	155	31.0%

Data & analysis: Evidence, Thomson Reuters

Chart 2.03.03 Number of physics and materials sciences papers
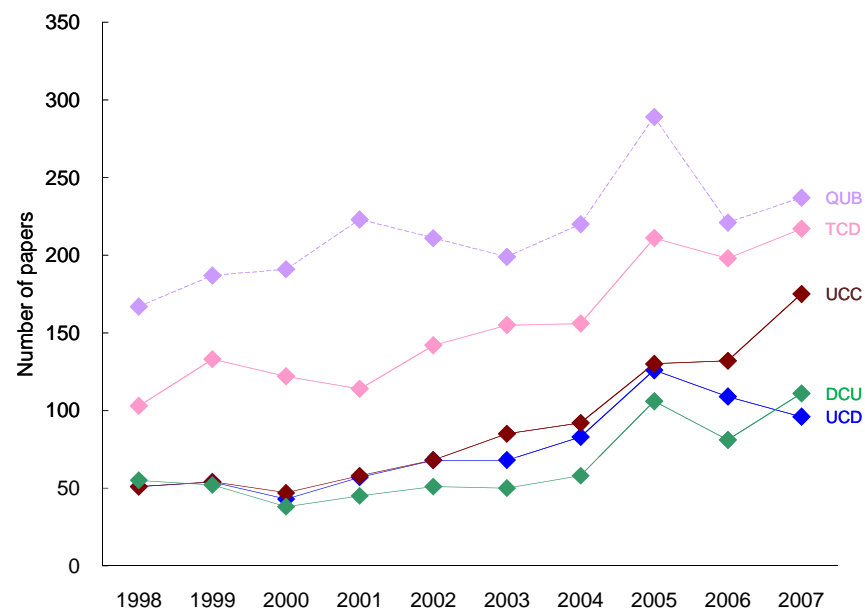
Data & analysis: Evidence, Thomson Reuters

Commentary

For several large institutions, growth in this area is well above their norm. TCD has clearly the highest baseline, other than QUB's, and unsurprisingly grows by a smaller proportion but UCC also has a particularly high share of national activity and has more than doubled activity between the early and later periods. QUB by contrast has grown very little.

The chart shows the degree to which TCD has maintained its leading position and has moved up in volume towards QUB. UCC's rise is also quite evident while the graph shows that UCD has fallen back from an upward trend on the middle part of the decade. DIAS also has a relatively high volume and good growth in this area.

Table 2.03.04 Number of chemical sciences papers

Chart 2.03.04 Number of chemical sciences papers

	5-year total, 1998-2002	5-year total, 2003-2007	change
University College Dublin (UCD)	258	396	34.8%
Trinity College Dublin (TCD)	309	490	36.9%
University College Cork (UCC)	257	397	35.3%
NUI Galway (NUIG)	105	120	12.5%
Dublin City University (DCU)	279	348	19.8%
University of Limerick (UL)	86	161	46.6%
NUI Maynooth (NUIM)	35	50	30.0%
Royal College of Surgeons in Ireland (RCSI)	21	50	58.0%
Dublin IT (DIT)	69	98	29.6%
Dublin Institute for Advanced Studies (DIAS)	data too sparse to index		
data for other Irish HE institutions not analysed			
Queens University Belfast (QUB)	567	632	10.3%
University of Ulster (UU)	65	110	40.9%

Data & analysis: Evidence, Thomson Reuters

Data & analysis: Evidence, Thomson Reuters

Commentary

Growth between the early and late periods is substantial but broadly in line with institutional averages. There is a noticeable spread of activity across a number of institutions, rather than the concentration in just a few, and this must provide a good basis for a network. TCD is the largest HEI, as in the physical sciences and in contrast to biological sciences.

As in physical sciences, TCD has a consistently rising volume which now places it close to QUB. UCC also has progressive growth, while UCD has been somewhat erratic in its progress.

Table 2.03.05 Number of civil engineering papers

	5-year total, 1998-2002	5-year total, 2003-2007	change
University College Dublin (UCD)	22	40	45.0%
Trinity College Dublin (TCD)	23	53	56.6%
University College Cork (UCC)		data too sparse to index	
NUI Galway (NUIG)		data too sparse to index	
Dublin City University (DCU)		data too sparse to index	
University of Limerick (UL)		data too sparse to index	
NUI Maynooth (NUIM)		data too sparse to index	
Royal College of Surgeons in Ireland (RCSI)		data too sparse to index	
Dublin IT (DIT)		data too sparse to index	
Dublin Institute for Advanced Studies (DIAS)		data too sparse to index	
data for other Irish HE institutions not analysed			
Queens University Belfast (QUB)	43	64	32.8%
University of Ulster (UU)	27	39	30.8%

Data & analysis: Evidence, Thomson Reuters

Chart 2.03.05 Number of civil engineering papers
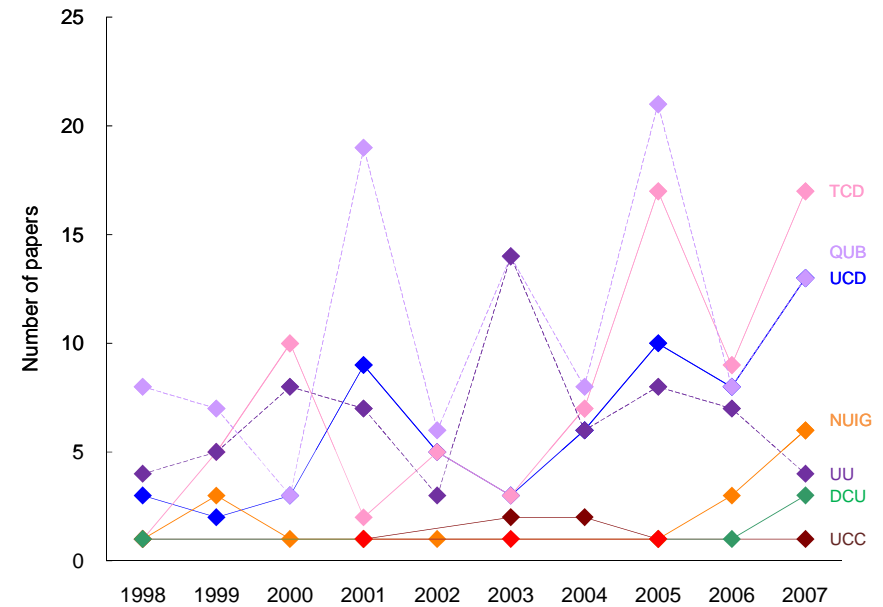
Data & analysis: Evidence, Thomson Reuters

Commentary

There is a similar, but surprisingly small, volume of research at TCD, UCD and QUB. Growth has been substantial on this small base, and greater in Ireland than Northern Ireland. Overall, however, published research volume is surprisingly small.

The institutional profiles are erratic: a consequence of small baseline volumes. Year on year changes are substantial. It is apparent that UU has somewhat dropped back and the three larger HEIs are on a more likely growth trend. However, the annual volumes are really very small for the size of these institutions.

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Table 2.03.06 Number of electrical engineering, electronic engineering, information engineering papers

	5-year total, 1998-2002	5-year total, 2003-2007	change
University College Dublin (UCD)	88	137	35.8%
Trinity College Dublin (TCD)	72	132	45.5%
University College Cork (UCC)	200	298	32.9%
NUI Galway (NUIG)	26	45	42.2%
Dublin City University (DCU)	67	157	57.3%
University of Limerick (UL)	57	164	65.2%
NUI Maynooth (NUIM)	21	100	79.0%
Royal College of Surgeons in Ireland (RCSI)	data too sparse to index		
Dublin IT (DIT)	19	65	70.8%
Dublin Institute for Advanced Studies (DIAS)	data too sparse to index		
data for other Irish HE institutions not analysed			
Queens University Belfast (QUB)	235	398	41.0%
University of Ulster (UU)	68	76	10.5%

Data & analysis: Evidence, Thomson Reuters

Chart 2.03.06 Number of electrical engineering, electronic engineering, information engineering papers
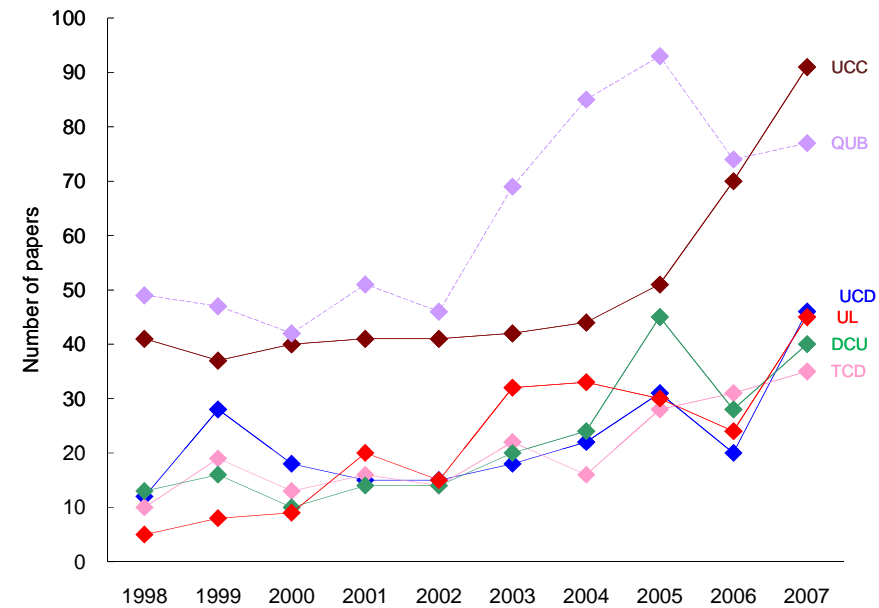
Data & analysis: Evidence, Thomson Reuters

Commentary

This is the most active publication area for Irish engineering. This is an area of exceptional volume for UCC. QUB is the larger institution and also shows very strong growth between the early and late periods which is not typical of its growth in other subject areas. Most Irish institutions have a substantial increase in output, with a near trebling in several of the medium-sized HEIs.

The graph shows that UCC's growth over the period has been most significant very recently and it has now overtaken QUB on a rising trajectory. This is an exceptional growth pattern. These two institutions are now well ahead of the other Irish HEIs, of which four have very similar volume and growth through the decade.

Table 2.03.07 Number of mechanical engineering papers

	5-year total, 1998-2002	5-year total, 2003-2007	change
University College Dublin (UCD)	88	76	-15.8%
Trinity College Dublin (TCD)	72	108	33.3%
University College Cork (UCC)	36	52	30.8%
NUI Galway (NUIG)	33	40	17.5%
Dublin City University (DCU)	18	43	58.1%
University of Limerick (UL)	41	83	50.6%
NUI Maynooth (NUIM)	data too sparse to index		
Royal College of Surgeons in Ireland (RCSI)	data too sparse to index		
Dublin IT (DIT)	data too sparse to index		
Dublin Institute for Advanced Studies (DIAS)	data too sparse to index		
data for other Irish HE institutions not analysed			
Queens University Belfast (QUB)	73	134	45.5%
University of Ulster (UU)	30	49	38.8%

Data & analysis: Evidence, Thomson Reuters

Chart 2.03.07 Number of mechanical engineering papers
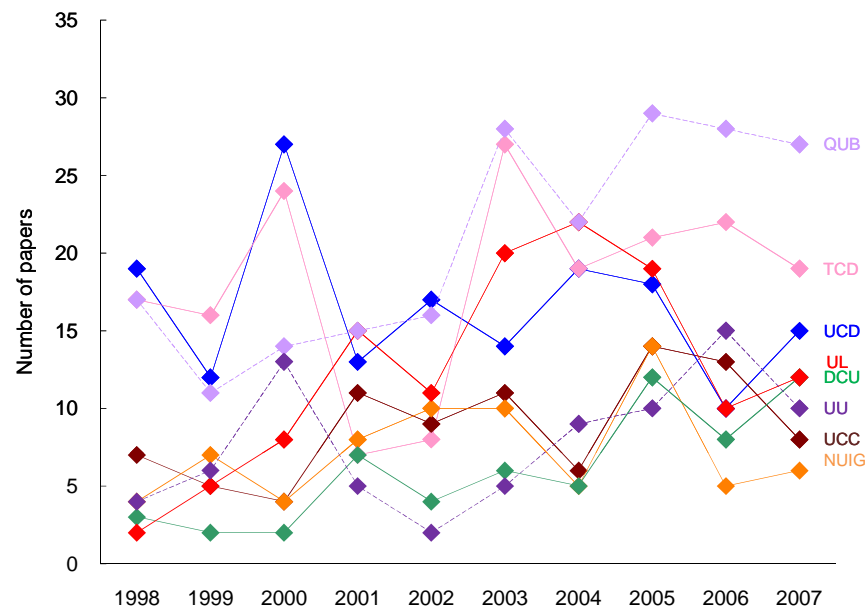
Data & analysis: Evidence, Thomson Reuters

Commentary

QUB has the largest volume and above average growth, like electrical engineering and atypically for its norm. TCD is the largest Irish HEI, with average growth but not a very great volume, while UCC has actually declined between the early and late periods. Several institutions have moderate outputs around 10 papers per year. Like civil engineering, this is not a major focus of academic research activity.

The graph shows a high level of year to year variation in output which makes trends difficult to discern. QUB has generally remained the largest institution but UCC had a more active period on the early years of the decade while TCD has a more stable annual productivity.

Table 2.05 Citation impact

	5-year average, 1998-2002	5-year average, 2003-2007	change
University College Dublin (UCD)	1.05	1.27	23%
Trinity College Dublin (TCD)	1.43	1.49	6%
University College Cork (UCC)	1.35	1.15	-20%
NUI Galway (NUIG)	0.88	0.98	10%
Dublin City University (DCU)	1.00	1.08	7%
University of Limerick (UL)	0.96	0.74	-22%
NUI Maynooth (NUIM)	0.99	0.99	0%
Royal College of Surgeons in Ireland (RCSI)	1.14	1.62	47%
Dublin IT (DIT)	1.15	1.05	-11%
Dublin Institute for Advanced Studies (DIAS)	0.68	1.25	58%
Other Irish HE institutions	0.91	0.88	-3%
Queens University Belfast (QUB)	1.12	1.20	8%
University of Ulster (UU)	0.91	0.87	-4%

Data & analysis: Evidence, Thomson Reuters

Chart 2.05 Citation impact
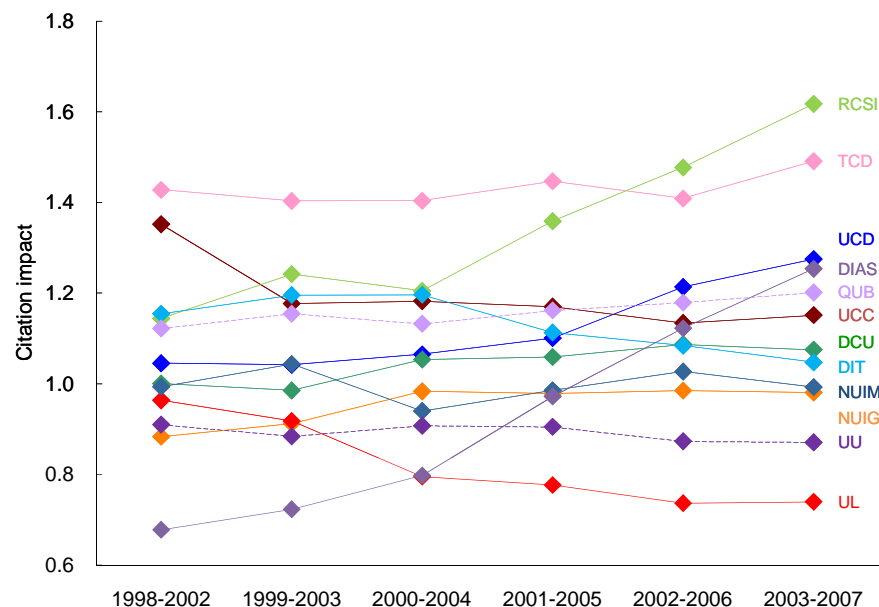
Data & analysis: Evidence, Thomson Reuters

Commentary

Impact is indexed as citations per paper, compared with relevant world averages to take account of the fields and years in which papers are published. This index is called citation impact (sometimes rebased impact or RBI). Because of volatility in annual data, the analysis here uses five-year windows. For most Irish HEIs the citation impact of their publications has increased, so they have improved relative to world averages. TCD has been a consistent leader over the decade, but UCD has improved by a greater margin while RCSI has an exceptional profile of change. UCC had a marked drop early in the period, but UL declined progressively throughout.

The graph shows the strong rise for RCSI. Most other institutions have a more stable profile, with TCD a clear leader. However, the rising profile for UCD can be seen, overtaking QUB, as can the steep rise for DIAS from a rear position right past most other colleges. These moving five-year windows provide a sound overall impression because they absorb outlier years, so apparent trends are usually reliable information. They also overcome a tendency for a fall in impact in the most recent year in systems undergoing expansion.
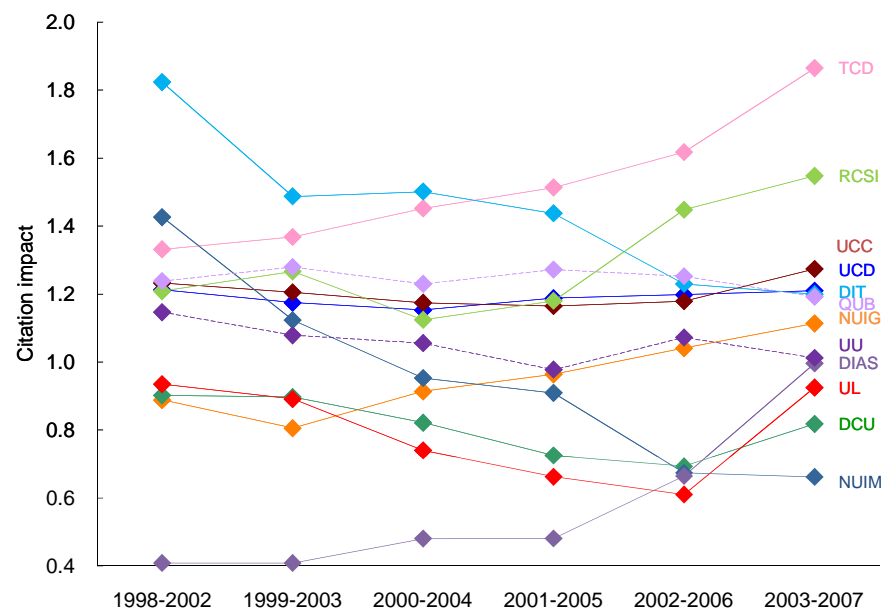
Table 2.06.01 Citation impact of clinical papers

Chart 2.06.01 Citation impact of clinical papers

	5-year average, 1998-2002	5-year average, 2003-2007	change
University College Dublin (UCD)	1.21	1.21	0%
Trinity College Dublin (TCD)	1.33	1.86	53%
University College Cork (UCC)	1.23	1.27	4%
NUI Galway (NUIG)	0.89	1.11	23%
Dublin City University (DCU)	0.90	0.82	-8%
University of Limerick (UL)	0.93	0.92	-1%
NUI Maynooth (NUIM)	1.43	0.66	-77%
Royal College of Surgeons in Ireland (RCSI)	1.21	1.55	34%
Dublin IT (DIT)	1.82	1.20	-62%
Dublin Institute for Advanced Studies (DIAS)	data too sparse to index		
Other Irish HE institutions	0.56	0.59	3%
Queens University Belfast (QUB)	1.24	1.19	-5%
University of Ulster (UU)	1.15	1.01	-13%

Data & analysis: Evidence, Thomson Reuters

Data & analysis: Evidence, Thomson Reuters

Commentary

TCD has improved its performance on a strong base in the early period. UCD has no change in impact, but this should be seen in the context of significant growth on a substantial base which may have diluted some strengths. NUIG has improved its impact with a growing volume. RCSI has a strong and improving position on impact despite its static share. The marked fall in performance for NUIM and DIT is associated with relatively small volumes. Both QUB and UU experience a decline in impact between early and late periods.

The improving and lead position for TCD and RCSI is clear in the graph. Given the level of international competition this is a significant performance. The graph also shows that most institutions have a broadly level impact over the period. NUIG shows the most consistent improvement, on its growing volume.

Table 2.06.02 Citation impact of health & medically-related papers

	5-year average, 1998-2002	5-year average, 2003-2007	change
University College Dublin (UCD)	0.90	1.36	46%
Trinity College Dublin (TCD)	1.30	1.16	-14%
University College Cork (UCC)	1.22	0.97	-25%
NUI Galway (NUIG)	0.92	1.09	17%
Dublin City University (DCU)	1.15	0.95	-20%
University of Limerick (UL)	0.36	0.67	31%
NUI Maynooth (NUIM)	0.58	0.65	7%
Royal College of Surgeons in Ireland (RCSI)	1.12	1.68	56%
Dublin IT (DIT)	0.94	1.16	22%
Dublin Institute for Advanced Studies (DIAS)	data too sparse to index		
Other Irish HE institutions	0.64	0.97	33%
Queens University Belfast (QUB)	0.92	1.09	16%
University of Ulster (UU)	0.98	0.90	-9%

Data & analysis: Evidence, Thomson Reuters

Chart 2.06.02 Citation impact of health & medically-related papers
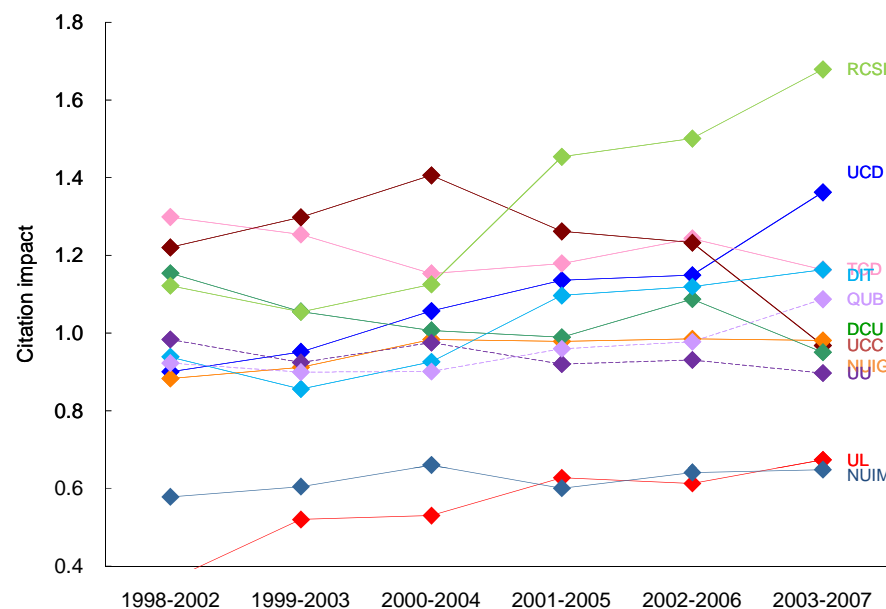
Data & analysis: Evidence, Thomson Reuters

Commentary

There is marked improvement in impact for RCSI, from an already good base. UCD has also improved from below world-average. By contrast, both TCD and UCC have fallen back, the latter dipping below world average in the later period. This is an area where performance can be patchy globally, as the research base is still maturing in some relevant disciplines. Erratic changes in impact can occur at national level.

RCSI's rising profile is very evident and UCD can be seen to rise consistently in successive windows. Other institutions generally seem to have a broadly level profile over the decade. The exception is UCC which drops from well above world average from 2000-2004 to the present.

Table 2.06.03 Citation impact of biological sciences papers

	5-year average, 1998-2002	5-year average, 2003-2007	change
University College Dublin (UCD)	1.05	1.28	30%
Trinity College Dublin (TCD)	1.82	1.54	-27%
University College Cork (UCC)	1.68	1.25	-43%
NUI Galway (NUIG)	0.74	0.95	21%
Dublin City University (DCU)	1.06	0.87	-19%
University of Limerick (UL)	1.07	1.26	19%
NUI Maynooth (NUIM)	1.54	1.07	-47%
Royal College of Surgeons in Ireland (RCSI)	1.01	1.45	44%
Dublin IT (DIT)	1.29	1.03	-26%
Dublin Institute for Advanced Studies (DIAS)	data too sparse to index		
Other Irish HE institutions	0.89	0.95	6%
Queens University Belfast (QUB)	1.18	1.01	-18%
University of Ulster (UU)	1.18	0.94	-23%

Data & analysis: Evidence, Thomson Reuters

Chart 2.06.03 Citation impact of biological sciences papers

Data & analysis: Evidence, Thomson Reuters

Commentary

Despite a smaller volume, and a marked drop in the most recent period, TCD has retained a clear lead on impact. UCC has also seen a severe reduction in impact from an excellent position in the first five-year period. UCD, however, has substantially improved its impact in this globally competitive area, as has RCSI. Although NUIG has improved the impact of its expanded output it remains below world average. Other institutions have not been able to maintain impact with growth.
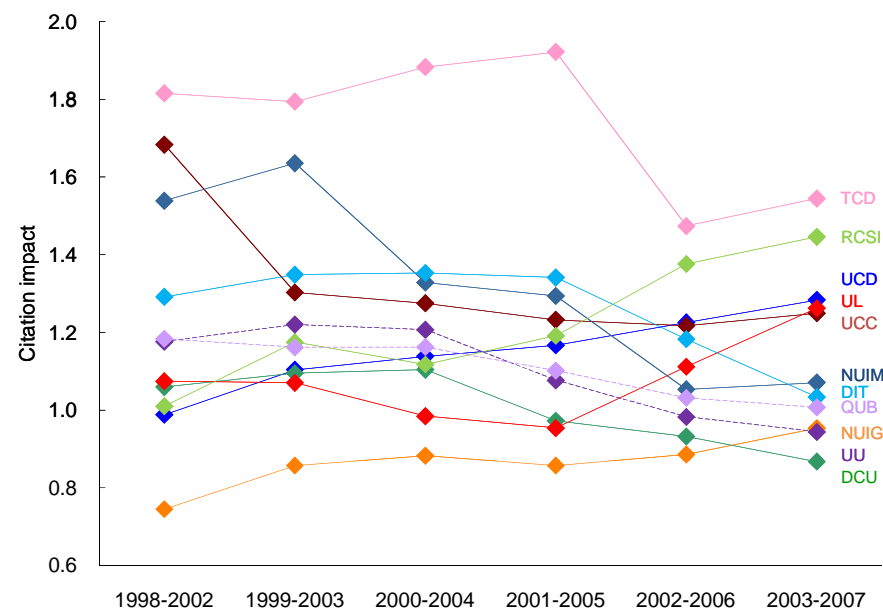
The graph confirms the consistency of decline in impact for a number of institutions, possibly due to the challenge of competition alongside expansion. The rising profile of UCD and RCSI are also evident, while TCD appears to have suffered a particular aberration within an otherwise rising line; this may deserve further investigation.

Table 2.06.04 Citation impact of environment papers

	5-year average, 1998-2002	5-year average, 2003-2007	change
University College Dublin (UCD)	0.92	1.11	19%
Trinity College Dublin (TCD)	1.14	1.23	9%
University College Cork (UCC)	0.87	1.02	15%
NUI Galway (NUIG)	0.97	1.02	5%
Dublin City University (DCU)	1.13	0.57	-56%
University of Limerick (UL)	0.38	0.71	33%
NUI Maynooth (NUIM)	0.99	0.83	-16%
Royal College of Surgeons in Ireland (RCSI)	data too sparse to index		
Dublin IT (DIT)	0.92	0.76	-16%
Dublin Institute for Advanced Studies (DIAS)	0.40	1.21	81%
Other Irish HE institutions	0.41	1.09	68%
Queens University Belfast (QUB)	1.35	1.21	-15%
University of Ulster (UU)	0.77	0.91	14%

Data & analysis: Evidence, Thomson Reuters

Chart 2.06.04 Citation impact of environment papers
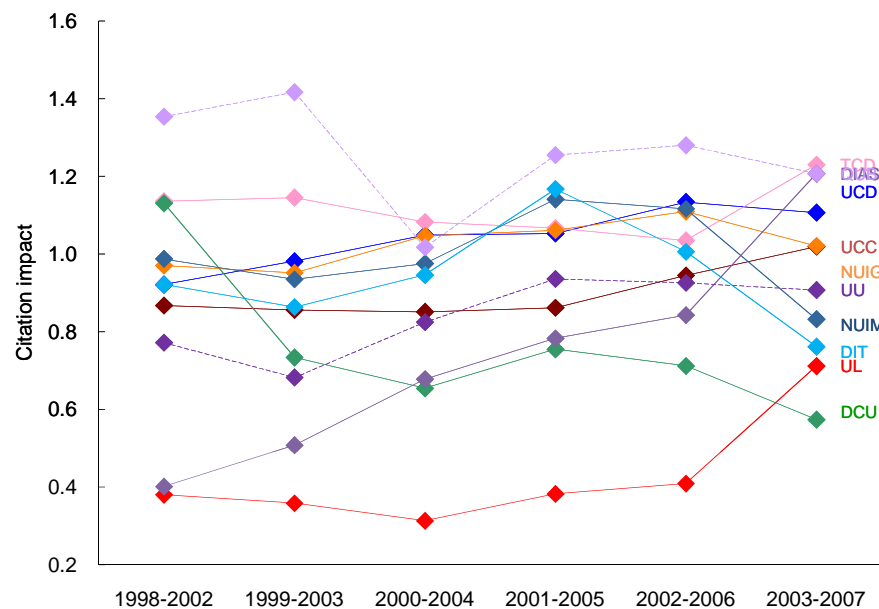
Data & analysis: Evidence, Thomson Reuters

Commentary

Impact has improved from below to above world average for the four largest Ireland HEIs in this area. This contrasts with Northern Ireland where impact has fallen for QUB despite its greater capacity, and remains below world benchmark for UU. However, this is not an area of evident overall strength although both TCD and QUB are individually good.

The graph tends to confirm the impression that this is not an area where any HEI stands out particularly strongly while several have weak performance on a low volume. DIAS has improved consistently on a rapidly growing volume, but that volume is as yet very small. Despite its strong growth, NUIG has only maintained a position around world average.

Table 2.06.05 Citation impact of mathematics papers

	5-year average, 1998-2002	5-year average, 2003-2007	change
University College Dublin (UCD)	0.97	0.67	-29%
Trinity College Dublin (TCD)	0.85	2.19	134%
University College Cork (UCC)	1.00	1.20	19%
NUI Galway (NUIG)	1.14	0.73	-42%
Dublin City University (DCU)	1.07	0.97	-11%
University of Limerick (UL)	0.65	0.31	-34%
NUI Maynooth (NUIM)	0.64	0.79	16%
Royal College of Surgeons in Ireland (RCSI)	1.99	0.53	-146%
Dublin IT (DIT)	1.38	0.65	-73%
Dublin Institute for Advanced Studies (DIAS)	0.47	0.85	38%
Other Irish HE institutions	0.31	0.37	6%
Queens University Belfast (QUB)	0.69	0.97	28%
University of Ulster (UU)	0.42	1.00	58%

Data & analysis: Evidence, Thomson Reuters

Chart 2.06.05 Citation impact of mathematics papers
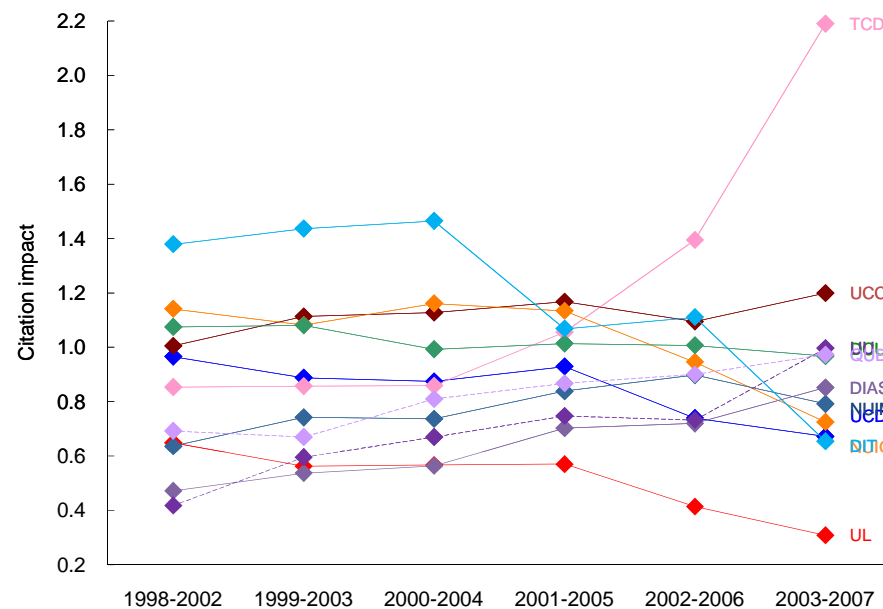
Data & analysis: Evidence, Thomson Reuters

Commentary

The variation in impact for mathematics research needs to be treated with some caution. A small number of outlier papers with exceptional impact can significantly affect outcomes and bibliometrics are unreliable as an indicator in these disciplines. The variation between HEIs is more extreme than in many areas, as is the shift between early and late periods. The exceptional leap upwards of TCD is notable and may be attributable to a particular discovery. It is notable that many of the recent five-year impact averages are below world average.

The graph shows relatively stable trends across the period for most institutions, despite the contrast in the table. The clear exceptions are the steep upwards trend for TCD after 2001 and the slight but consistent downward trend for UCD. DIT also declines but on a much smaller volume.

Table 2.06.06 Citation impact of physical sciences papers

	5-year average, 1998-2002	5-year average, 2003-2007	change
University College Dublin (UCD)	1.23	1.83	60%
Trinity College Dublin (TCD)	1.56	1.65	10%
University College Cork (UCC)	1.14	1.17	3%
NUI Galway (NUIG)	0.72	0.89	17%
Dublin City University (DCU)	1.01	0.99	-2%
University of Limerick (UL)	1.13	0.70	-42%
NUI Maynooth (NUIM)	1.01	1.03	2%
Royal College of Surgeons in Ireland (RCSI)	1.90	1.80	-10%
Dublin IT (DIT)	1.37	0.95	-42%
Dublin Institute for Advanced Studies (DIAS)	0.75	1.33	58%
Other Irish HE institutions	1.34	0.94	-41%
Queens University Belfast	1.21	1.47	26%
University of Ulster (UU)	1.30	0.93	-37%

Data & analysis: Evidence, Thomson Reuters

Chart 2.06.06 Citation impact of physical sciences papers
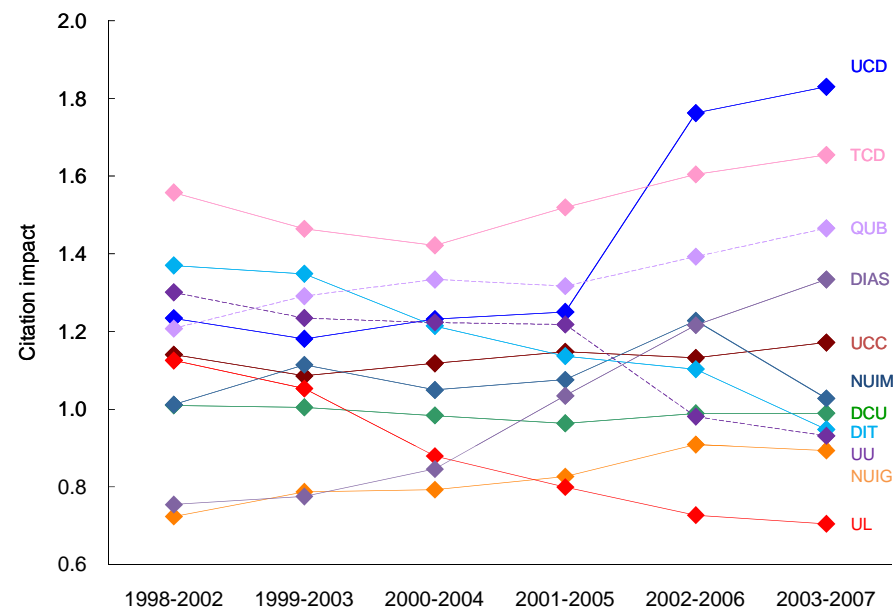
Data & analysis: Evidence, Thomson Reuters

Commentary

Note that RCSI has a very small volume (fewer than 10 papers per year) but some exceptional publications which lift its average impact and, in the middle of the decade, create an exceptional peak not charted here. TCD has a strong and consistent position, early and late, but UCD has a marked improvement. QUB also improves on a good impact base. DIAS, for which this is the key focus, has a very strong impact improvement from well below to well above world average. DCU, which also has good volume, maintains a position close to the world benchmark.

The chart shows some trend to separate leading units, well above world average, and others on a declining profile. TCD has a consistent lead and rising trend, followed by QUB, except in the last two five-year windows where UCD leaps ahead. DIAS can be seen to progressively improve right the way through and UCC maintains a level profile. Below this, other institutions drop back. As noted, the profile for RCSI – presumably a spin-off of related medical activity - is essentially unplottable.

Table 2.06.07 Citation impact of engineering papers

	5-year average, 1998-2002	5-year average, 2003-2007	change
University College Dublin (UCD)	1.18	0.91	-27%
Trinity College Dublin (TCD)	0.90	1.31	41%
University College Cork (UCC)	1.19	1.07	-12%
NUI Galway (NUIG)	0.90	0.83	-7%
Dublin City University (DCU)	0.92	1.29	37%
University of Limerick (UL)	1.18	0.63	-55%
NUI Maynooth (NUIM)	0.67	1.31	63%
Royal College of Surgeons in Ireland (RCSI)	1.83	2.31	49%
Dublin IT (DIT)	0.88	1.34	46%
Dublin Institute for Advanced Studies (DIAS)	0.29	1.22	93%
Other Irish HE institutions	0.86	0.75	-11%
Queens University Belfast (QUB)	0.89	0.91	2%
University of Ulster (UU)	0.81	0.95	14%

Data & analysis: Evidence, Thomson Reuters

Chart 2.06.07 Citation impact of engineering papers
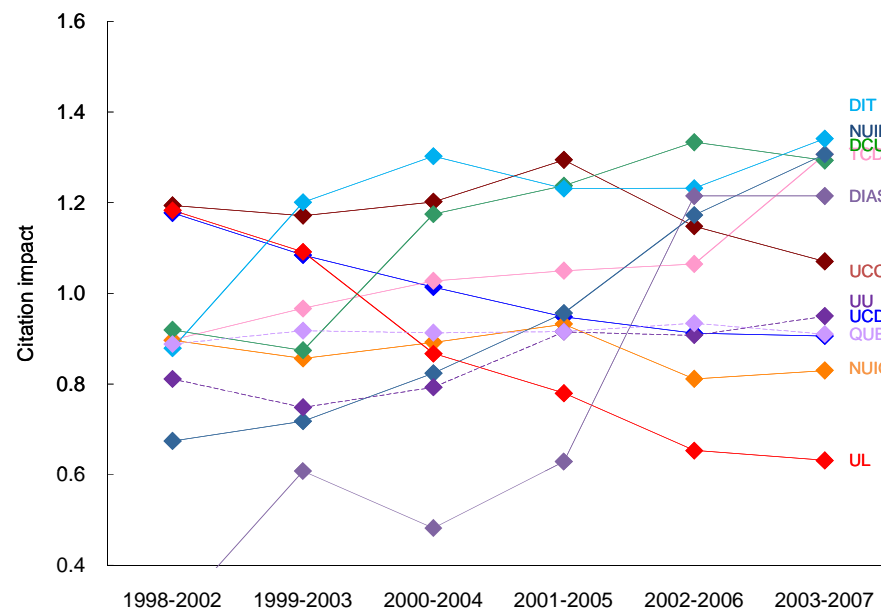
Data & analysis: Evidence, Thomson Reuters

Commentary

Bibliometric impact is agreed generally to be only a weak indicator of performance in engineering research. TCD and UCD and QUB have good and improving impact on their volume while UCC has expanded rapidly at some cost to impact. RCSI has exceptional impact on a tiny volume, as in physical sciences. Many institutions vary around world average, a pattern seen in other jurisdictions where many engineering units have a mixed pure and applied portfolio.

The graph shows improving profile for several smaller institutions as well as a consistent performance from TCD. It also confirms the impression from the table that UL, despite its relatively high volume in this area, has falling impact, consistently through the sequence.

Table 2.06.08 Citation impact of social science papers

	5-year average, 1998-2002	5-year average, 2003-2007	change
University College Dublin (UCD)	0.72	1.06	33%
Trinity College Dublin (TCD)	0.92	0.99	7%
University College Cork (UCC)	0.79	0.97	18%
NUI Galway (NUIG)	0.53	0.81	28%
Dublin City University (DCU)	0.53	0.79	26%
University of Limerick (UL)	0.67	0.42	-24%
NUI Maynooth (NUIM)	0.58	0.63	5%
Royal College of Surgeons in Ireland (RCSI)	0.83	0.64	-19%
Dublin IT (DIT)	0.28	0.55	28%
Dublin Institute for Advanced Studies (DIAS)	data too sparse to index		
Other Irish HE institutions	0.62	0.60	-3%
Queens University Belfast (QUB)	0.87	0.98	11%
University of Ulster (UU)	0.66	0.81	15%

Data & analysis: Evidence, Thomson Reuters

Chart 2.06.08 Citation impact of social science papers
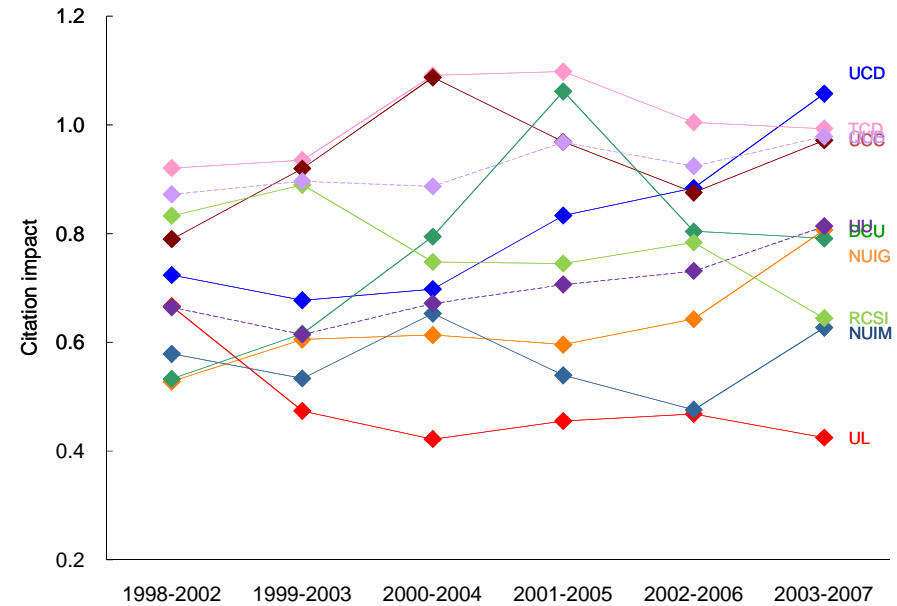
Data & analysis: Evidence, Thomson Reuters

Commentary

Bibliometrics are generally agreed to be a weak indicator of research quality for social sciences, where citation density is sparse. Most institutions have improved in average impact between the early and late periods. With the exception of UCD, however, no institution actually produces a research portfolio that is typically cited more often than world average. This includes both QUB and UU, despite their well-established larger volume output.

The graph shows that impact can be volatile for the social sciences. The larger institutions generally have better impact across the period but there is only weak consistency. The overall impression is that research across the system is not yet strong in global comparisons.

Table 2.06.09 Citation impact of business papers

	5-year average, 1998-2002	5-year average, 2003-2007	change
University College Dublin (UCD)	0.76	1.06	29%
Trinity College Dublin (TCD)	0.92	0.71	-21%
University College Cork (UCC)	0.31	0.24	-8%
NUI Galway (NUIG)	0.40	0.53	13%
Dublin City University (DCU)	0.52	0.77	25%
University of Limerick (UL)	0.64	0.70	6%
NUI Maynooth (NUIM)	0.30	1.26	96%
Royal College of Surgeons in Ireland (RCSI)	data too sparse to index		
Dublin IT (DIT)	data too sparse to index		
Dublin Institute for Advanced Studies (DIAS)	data too sparse to index		
Other Irish HE institutions	0.28	0.50	22%
Queens University Belfast (QUB)	0.50	0.59	9%
University of Ulster (UU)	0.41	0.68	28%

Data & analysis: Evidence, Thomson Reuters

Chart 2.06.09 Citation impact of business papers
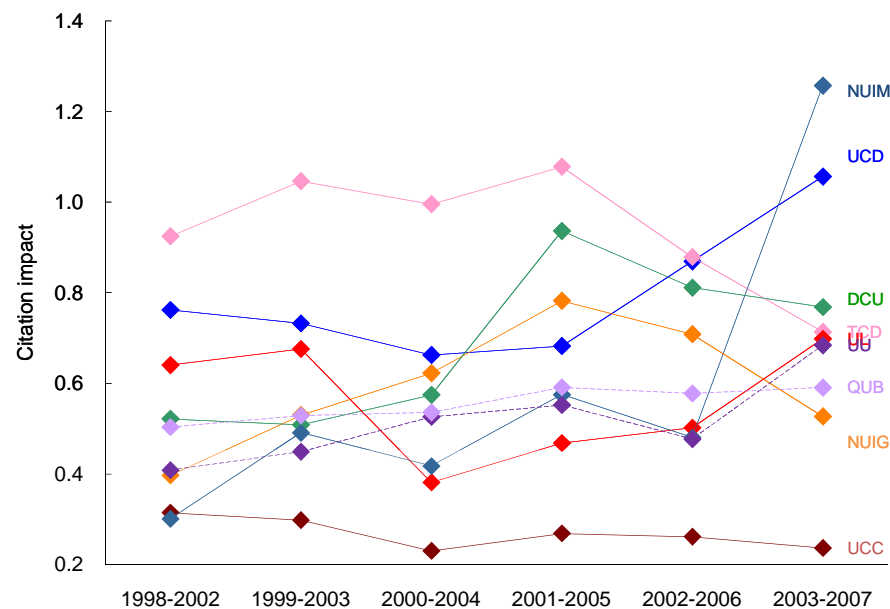
Data & analysis: Evidence, Thomson Reuters

Commentary

The impact of Irish research in the business area is generally well below world average, reflecting the cultural shift to a more academic approach elsewhere. UCD shows a progressive improvement over the period but the exceptional improvement for NUIM is from a very low base and may be unsustainable.

The very small volume of business output was noted previously. UCD is the only institution with significant volume and growth and its impact is now rising above world average. It is notable that TCD has slipped downwards over several years.

Table 2.06.10 Citation impact of arts and humanities papers

	5-year average, 1998-2002	5-year average, 2003-2007	change
University College Dublin (UCD)	0.77	0.95	18%
Trinity College Dublin (TCD)	1.00	1.07	7%
University College Cork (UCC)	0.86	0.56	-31%
NUI Galway (NUIG)	0.88	1.15	26%
Dublin City University (DCU)	0.37	0.56	19%
University of Limerick (UL)	0.48	0.73	25%
NUI Maynooth (NUIM)	0.72	0.72	0%
Royal College of Surgeons in Ireland (RCSI)	data too sparse to index		
Dublin IT (DIT)	1.09	0.71	-37%
Dublin Institute for Advanced Studies (DIAS)	data too sparse to index		
Other Irish HE institutions	0.59	0.96	37%
Queens University Belfast (QUB)	0.73	1.47	74%
University of Ulster (UU)	0.72	0.85	12%

Data & analysis: Evidence, Thomson Reuters

Chart 2.06.10 Citation impact of arts and humanities papers
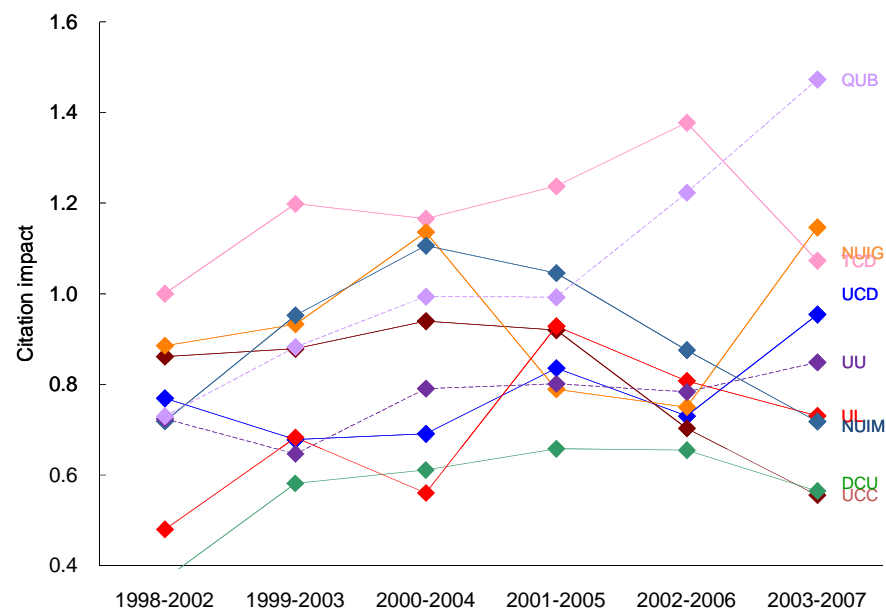
Data & analysis: Evidence, Thomson Reuters

Commentary

Citation impact of humanities research is universally agreed to be of very limited value as an indicator of performance, particularly where output volumes are low. Nonetheless, for interest, it is noteworthy that Irish HEIs are generally on an upward trend in this regard.

The strong and consistent upward trend for QUB stands out in this figure. Nonetheless, citation impact must be regarded as an indicator of limited value in these subjects.

Table 2.07.01 Citation impact of biological sciences: Organismal biology papers

	5-year average, 1998-2002	5-year average, 2003-2007	change
University College Dublin (UCD)	0.99	1.26	27%
Trinity College Dublin (TCD)	1.30	1.81	51%
University College Cork (UCC)	0.98	1.07	8%
NUI Galway (NUIG)	0.65	0.82	17%
Dublin City University (DCU)	0.58	0.54	-4%
University of Limerick (UL)	0.57	1.26	69%
NUI Maynooth (NUIM)	0.97	1.24	28%
Royal College of Surgeons in Ireland (RCSI)	1.57	0.68	-89%
Dublin IT (DIT)	2.45	1.10	-134%
Dublin Institute for Advanced Studies (DIAS)	data too sparse to index		
data for other Irish HE institutions not analysed			
Queens University Belfast (QUB)	1.04	0.90	-14%
University of Ulster (UU)	0.85	0.78	-8%

Data & analysis: Evidence, Thomson Reuters

Chart 2.07.01 Citation impact of biological sciences: Organismal biology papers
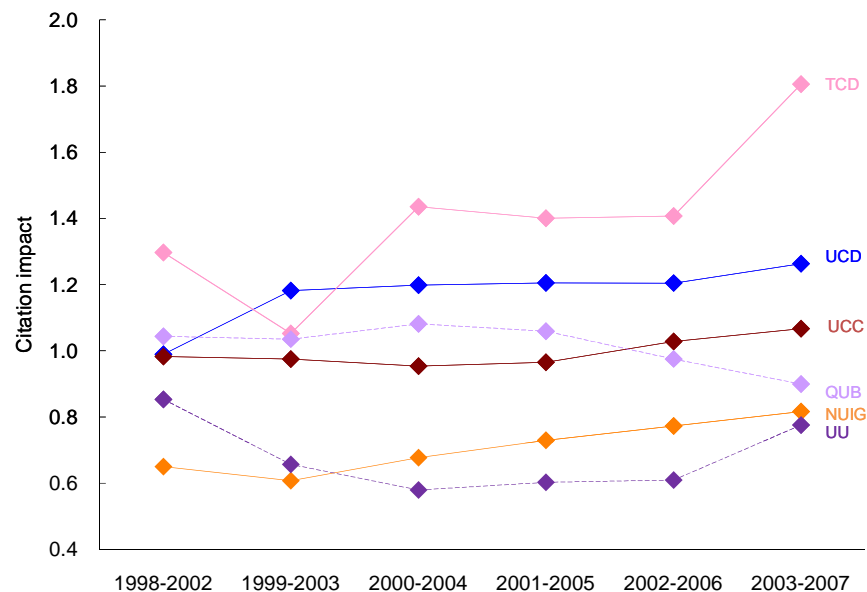
Data & analysis: Evidence, Thomson Reuters

Commentary

While there has been improvement in performance between the early and late periods, a number of institutions are performing on average below world benchmarks. UCD has improved and TCD has exceptional improvement so that it is well above world average in the later period. QUB by contrast has dropped below this level.

Most institutions actually have a very level profile, and UCD evidently had an atypical year early in the decade. The improvement for TCD from a strong initial base is more marked, however, and it seems to be consolidating its lead. QUB has unfortunately followed a consistent downward trend.

Table 2.07.02 Citation impact of biological sciences: Molecular & cellular biology papers

	5-year average, 1998-2002	5-year average, 2003-2007	change
University College Dublin (UCD)	0.72	1.24	52%
Trinity College Dublin (TCD)	2.06	1.48	-58%
University College Cork (UCC)	2.42	1.33	-109%
NUI Galway (NUIG)	0.75	1.03	28%
Dublin City University (DCU)	0.64	0.73	9%
University of Limerick (UL)	0.46	0.77	32%
NUI Maynooth (NUIM)	1.09	0.85	-24%
Royal College of Surgeons in Ireland (RCSI)	0.97	1.44	48%
Dublin IT (DIT)	1.57	0.81	-77%
Dublin Institute for Advanced Studies (DIAS)	data too sparse to index		
data for other Irish HE institutions not analysed			
Queens University Belfast (QUB)	1.06	0.88	-18%
University of Ulster (UU)	0.68	0.70	2%

Data & analysis: Evidence, Thomson Reuters

Chart 2.07.02 Citation impact of biological sciences: Molecular & cellular biology papers
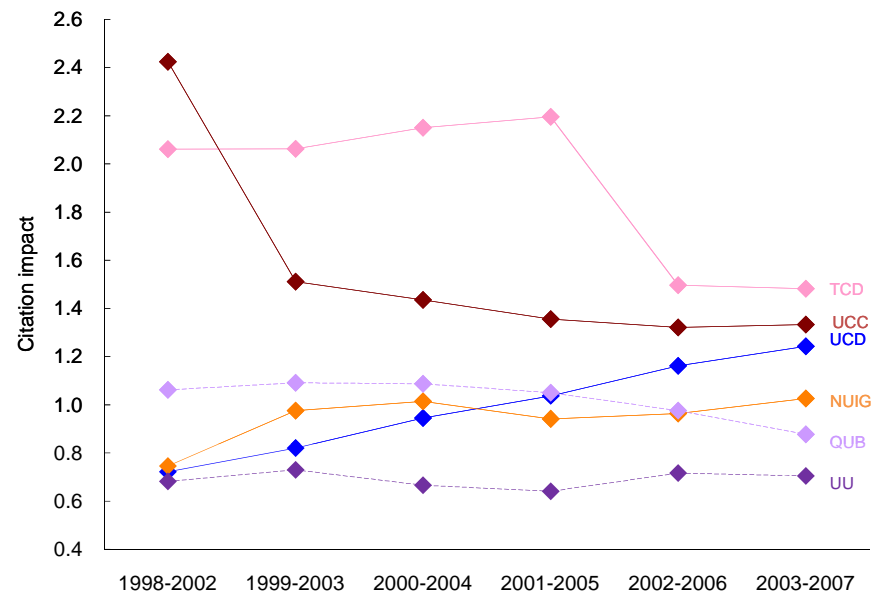
Data & analysis: Evidence, Thomson Reuters

Commentary

This is, as noted, a very competitive area in all countries. The changes for Ireland between the early and late period seem inconsistent and sometimes surprisingly substantial and this may be explained by international factors rather than domestic policy. However, there are also extreme outliers. UCC published a particular nucleic acids paper in 1998 which now has accumulated more than 10,000 cites. The point at which this paper drops out of the 'window' explains its apparently dramatic drop in impact. Some similar 2001 paper may explain the TCD shift.

The graph shows that UCD's much improved impact is part of a progressive trend. Other institutions including QUB either suffer dramatic falls, referred to opposite, or have essentially level profiles around but below world average. The performance of the three leading institutions is clearly critical to Irish success in this area.

2.07.03 Citation impact of Irish HE sector research relative to world baselines in 20 "project" research areas (selected)

Table 2.07.03 Citation impact of physics and materials sciences papers

	5-year average, 1998-2002	5-year average, 2003-2007	change
University College Dublin (UCD)	1.50	2.14	64%
Trinity College Dublin (TCD)	1.62	1.62	-1%
University College Cork (UCC)	0.95	1.23	28%
NUI Galway (NUIG)	0.74	0.85	12%
Dublin City University (DCU)	0.80	0.87	7%
University of Limerick (UL)	0.78	0.81	3%
NUI Maynooth (NUIM)	0.97	1.04	7%
Royal College of Surgeons in Ireland (RCSI)	data too sparse to index		
Dublin IT (DIT)	1.07	1.12	5%
Dublin Institute for Advanced Studies (DIAS)	0.75	1.34	60%
data for other Irish HE institutions not analysed			
Queens University Belfast (QUB)	1.04	1.34	30%
University of Ulster (UU)	0.88	0.79	-9%

Data & analysis: Evidence, Thomson Reuters

Chart 2.07.03 Citation impact of physics and materials sciences papers
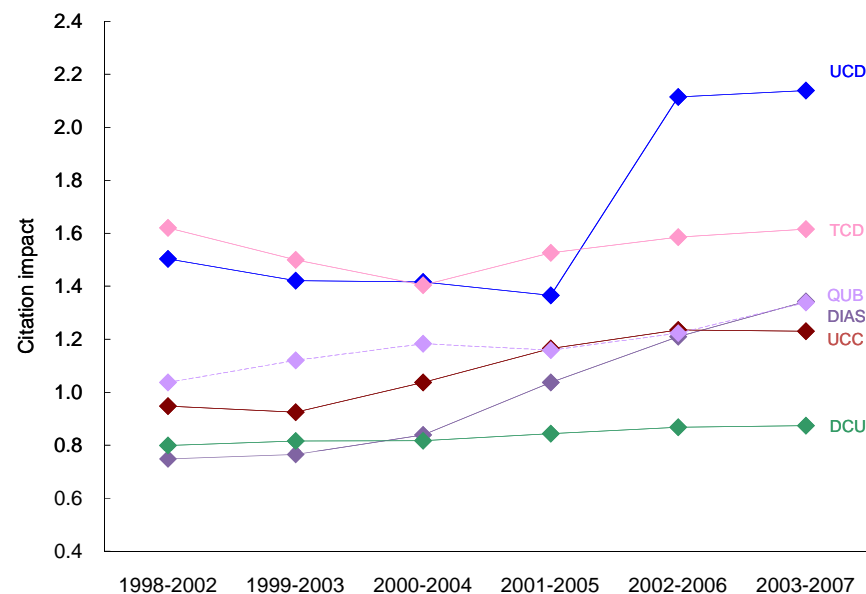
Data & analysis: Evidence, Thomson Reuters

Commentary

UCD and TCD start with very good impact in the early period while UCC improves significantly on its initially weaker performance. For both UCD and TCD, this is an extremely competitive performance in international terms. However, while UCC has improved, most other institutions are not above world average. The exception is DIAS, for which this is a key part of the institutional portfolio, and its performance improves substantially. QUB also shows some improvement albeit to a lesser degree.

The graph shows a relatively level profile for most institutions, with the progressive rising profile for DIAS. The exception is the sharp change in performance for UCD in 2002. The citation impact for UCC is influenced by a single paper, with more than 100 authors, titled 'Review of particle physics'. It has accumulated more than 850 citations.
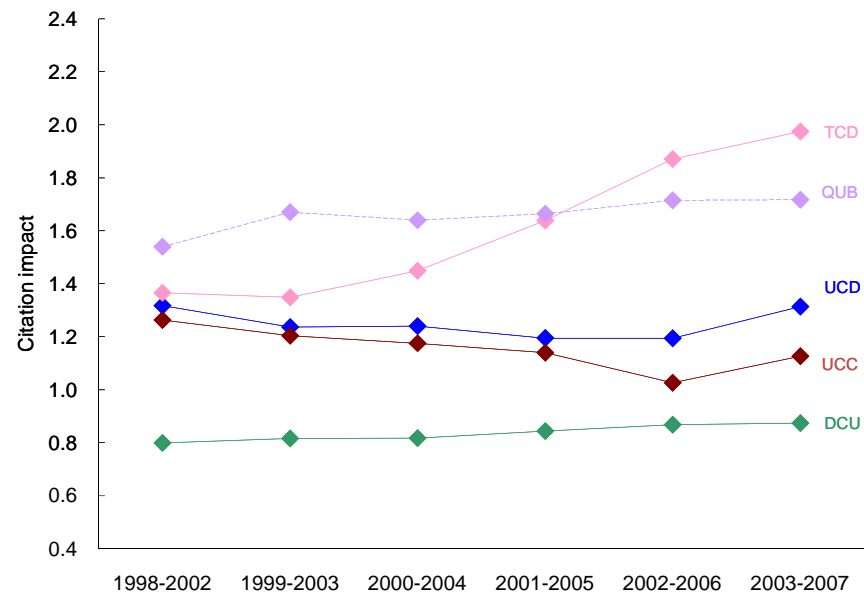
2.07.04 Citation impact of Irish HE sector research relative to world baselines in 20 "project" research areas (selected)

Table 2.07.04 Citation impact of chemical sciences papers

	5-year average, 1998-2002	5-year average, 2003-2007	change
University College Dublin (UCD)	1.32	1.31	0%
Trinity College Dublin (TCD)	1.37	1.98	61%
University College Cork (UCC)	1.26	1.13	-14%
NUI Galway (NUIG)	0.67	0.93	25%
Dublin City University (DCU)	1.15	1.14	-1%
University of Limerick (UL)	1.53	0.83	-71%
NUI Maynooth (NUIM)	1.37	0.89	-48%
Royal College of Surgeons in Ireland (RCSI)	2.00	1.82	-17%
Dublin IT (DIT)	1.30	1.07	-23%
Dublin Institute for Advanced Studies (DIAS)			
data for other Irish HE institutions not analysed			
Queens University Belfast (QUB)	1.54	1.72	18%
University of Ulster (UU)	0.99	1.30	30%

Data & analysis: Evidence, Thomson Reuters

Chart 2.07.04 Citation impact of chemical sciences papers

Data & analysis: Evidence, Thomson Reuters

Commentary

TCD has a marked improvement between the early and late periods, to a level close to twice world average impact. This compares with QUB which also improves but by a smaller margin. Other larger institutions have a consistent performance around world average.

The graph shows a relatively level profile for most institutions. It also shows that whereas TCD had a progressive improvement over several years, QUB's shift was at the start of the period and it then remained level.

2.07.05 Citation impact of Irish HE sector research relative to world baselines in 20 "project" research areas (selected)

Table 2.07.05 Citation impact of civil engineering papers

	5-year average, 1998-2002	5-year average, 2003-2007	change
University College Dublin (UCD)	0.63	1.08	45%
Trinity College Dublin (TCD)	0.50	1.32	83%
University College Cork (UCC)	data too sparse to index		
NUI Galway (NUIG)	data too sparse to index		
Dublin City University (DCU)	data too sparse to index		
University of Limerick (UL)	data too sparse to index		
NUI Maynooth (NUIM)	data too sparse to index		
Royal College of Surgeons in Ireland (RCSI)	data too sparse to index		
Dublin IT (DIT)	data too sparse to index		
Dublin Institute for Advanced Studies (DIAS)	data too sparse to index		
data for other Irish HE institutions not analysed			
Queens University Belfast (QUB)	0.76	1.04	28%
University of Ulster (UU)	0.82	0.72	-11%

Data & analysis: Evidence, Thomson Reuters

Chart 2.07.05 Citation impact of civil engineering papers
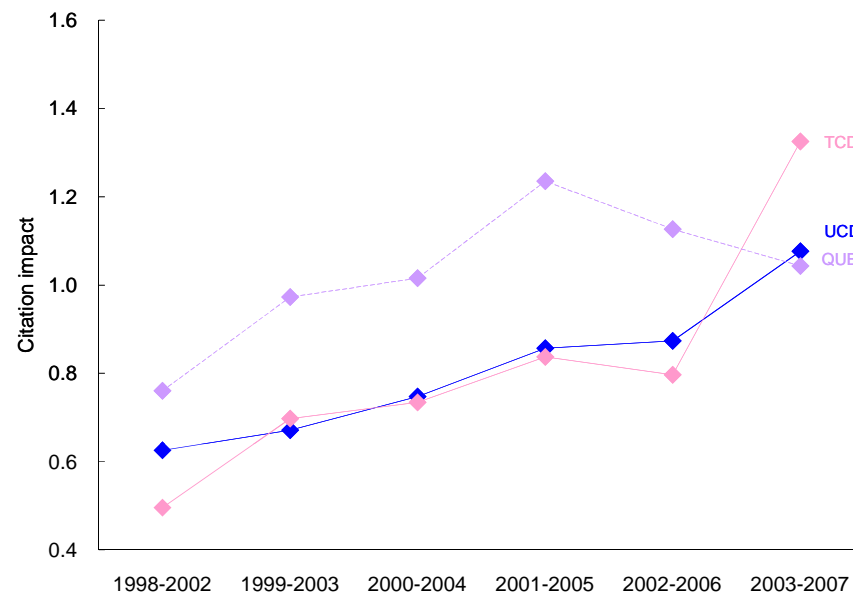
Data & analysis: Evidence, Thomson Reuters

Commentary

The analysis is presented for information but is based on very small volumes. It shows that the larger institutions (up from about 5 to about 10 papers per year on average) have improved their impact. While UCC appears to have a dramatically high value for impact these index values are based on 2 and 6 papers in each period (see Indicator 2.03.05). Similarly, UL's figure is based on just 2 papers.

The graph shows a gradually climbing profile for the three institutions graphed. UCD has a progressive improvement from around world average to a much stronger current position reflected well in the five-year windows. TCD's position is also progressively improving and it is now slightly ahead of UCD.

2.07.06 Citation impact of Irish HE sector research relative to world baselines in 20 "project" research areas (selected)

Table 2.07.06 Citation impact of electrical engineering, electronic engineering, information engineering papers

	5-year average, 1998-2002	5-year average, 2003-2007	change
University College Dublin (UCD)	1.13	1.53	40%
Trinity College Dublin (TCD)	1.00	1.07	7%
University College Cork (UCC)	1.42	1.35	-7%
NUI Galway (NUIG)	0.71	0.51	-20%
Dublin City University (DCU)	1.05	1.09	5%
University of Limerick (UL)	0.78	0.70	-8%
NUI Maynooth (NUIM)	0.90	1.53	62%
Royal College of Surgeons in Ireland (RCSI)	data too sparse to index		
Dublin IT (DIT)	0.95	1.68	73%
Dublin Institute for Advanced Studies (DIAS)	data too sparse to index		
data for other Irish HE institutions not analysed			
Queens University Belfast (QUB)	0.71	0.89	17%
University of Ulster (UU)	0.56	0.96	39%

Data & analysis: Evidence, Thomson Reuters

Chart 2.07.06 Citation impact of electrical engineering, electronic engineering, information engineering papers
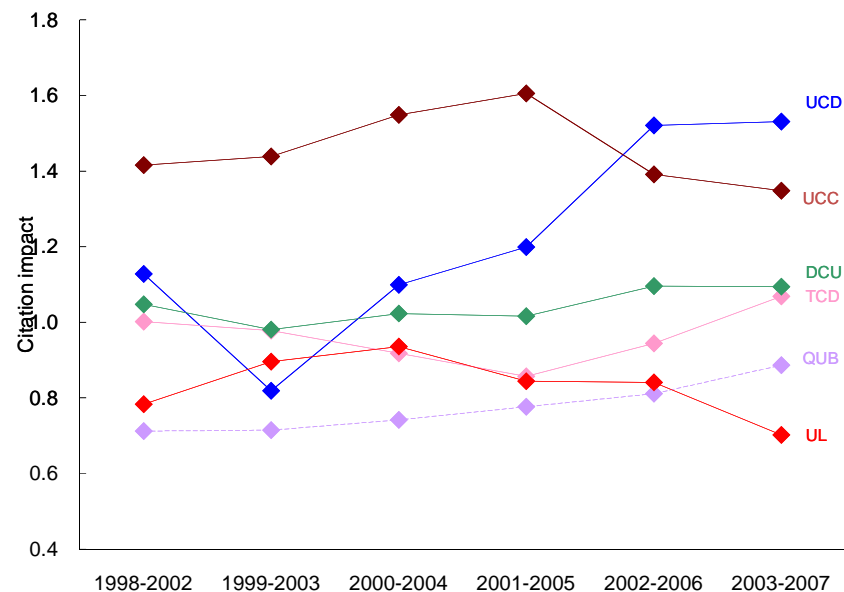
Data & analysis: Evidence, Thomson Reuters

Commentary

Ireland's research in this area has a clearly higher impact than Northern Ireland. Several of the larger institutions have improved their performance and UCD and UCC are well above world average. UL also had a significant volume (over 30 papers per year) but the citation impact has never been above world average and has fallen consistently since 2000.

UCD has a progressive improvement, from around world average to a much stronger current position. Otherwise, the graph shows a relatively level profile for most institutions. UCC has a recent dip but remains well above world average.

2.07.07 Citation impact of Irish HE sector research relative to world baselines in 20 "project" research areas (selected)

Table 2.07.07 Citation impact of mechanical engineering papers

	5-year average, 1998-2002	5-year average, 2003-2007	change
University College Dublin (UCD)	1.21	2.07	87%
Trinity College Dublin (TCD)	1.26	2.36	109%
University College Cork (UCC)	1.55	1.51	-4%
NUI Galway (NUIG)	0.85	0.95	10%
Dublin City University (DCU)	0.70	0.84	13%
University of Limerick (UL)	0.85	0.48	-37%
NUI Maynooth (NUIM)	data too sparse to index		
Royal College of Surgeons in Ireland (RCSI)	data too sparse to index		
Dublin IT (DIT)	data too sparse to index		
Dublin Institute for Advanced Studies (DIAS)	data too sparse to index		
data for other Irish HE institutions not analysed			
Queens University Belfast (QUB)	0.90	1.05	16%
University of Ulster (UU)	0.83	0.49	-34%

Data & analysis: Evidence, Thomson Reuters

Chart 2.07.07 Citation impact of mechanical engineering papers
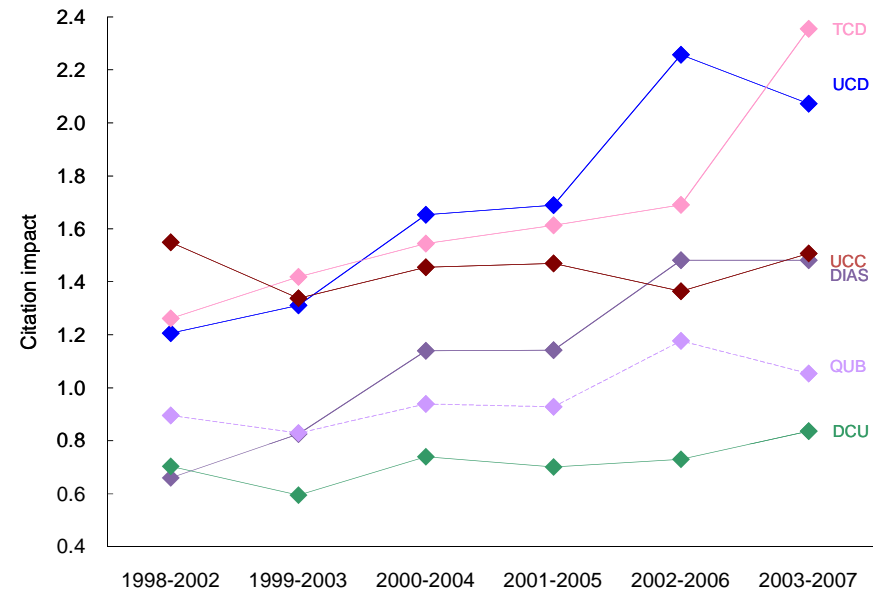
Data & analysis: Evidence, Thomson Reuters

Commentary

The impact of research at UCD and TCD has improved from good to outstanding between the early and late periods. Performance elsewhere has changed less but DIAS has improved on a small volume. QUB is around world average.

The graph shows a slightly rising profile for most institutions. Against this, the two large Dublin HEIs stand out with a progressive and continuous improvement through the decade and a sharp step-up in the last cycle. This is evidently an exceptional outcome for Irish research.
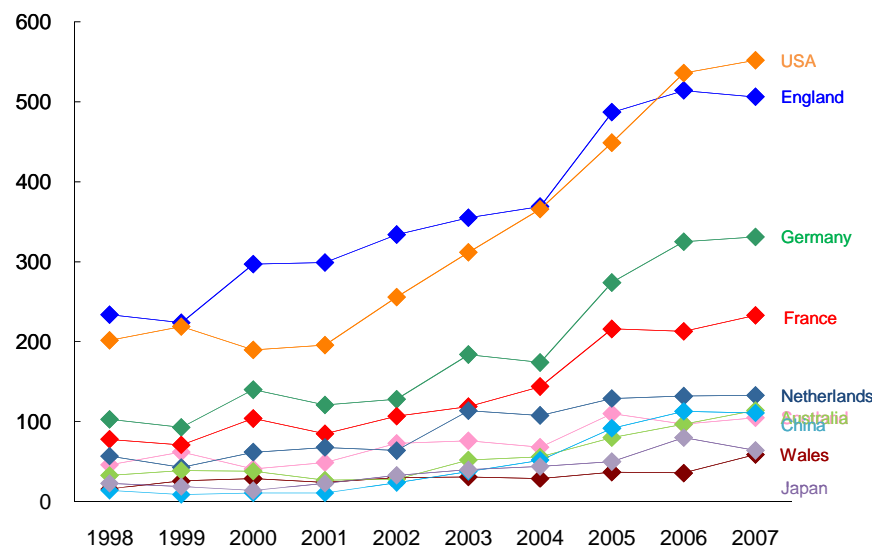
Table 3.01 International collaboration - total Ireland HE sector, number of papers

Chart 3.01 International collaboration - total Ireland HE sector, number of papers

	5-year total, 1998-2002	5-year total, 2003-2007	change	
England	1388	2231		37.8%
Scotland	271	456		40.6%
Wales	125	192		34.9%
USA	1063	2215		52.0%
Germany	585	1288		54.6%
France	445	925		51.9%
Netherlands	294	616		52.3%
Australia	165	399		58.6%
China	69	406		83.0%
Japan	112	278		59.7%

Data & analysis: Evidence, Thomson Reuters

Data & analysis: Evidence, Thomson Reuters

Commentary

International collaboration is rising at a significant rate. This rise is somewhat faster than would be expected for the global research base generally. That is likely to be a reflection both of expanding opportunities through greater research activity and output and of rising research impact which makes collaboration a more attractive prospect for partners. Both factors, opportunity and value, are critical to engagement. The strong links to the USA are very noticeable, and will be very beneficial, but the balance between the UK, France and Germany is unusual within the EU.

It is important therefore to note that collaboration is increasing more for mainland Europe than for the UK and more for Asia/Pacific than Europe. A rapid rise in China collaboration is possible because China itself has grown so rapidly, and many other countries see a similar pattern. Doubling links with many leading research countries in Europe is good news. It will provide excellent links to support further research growth for Ireland and keep activity at the forefront of EU initiatives. Links to the USA should be carefully maintained.

3.02   International collaboration - individual HE institutions in all research fields

Table 3.02 International collaboration - individual HE institutions, number of papers (10-year total)

	England	Scotland	Wales	USA	Germany	France	Netherlands	Australia	China	Japan
University College Dublin (UCD)	949	198	64	960	502	417	363	129	197	87
Trinity College Dublin (TCD)	949	175	139	739	439	359	181	150	62	101
University College Cork (UCC)	691	159	58	449	342	228	180	82	58	44
NUI Galway (NUIG)	310	72	18	418	156	69	67	44	105	39
Dublin City University (DCU)	153	40	11	219	104	102	26	67	8	17
University of Limerick (UL)	184	9	10	131	46	32	27	23	5	16
NUI Maynooth (NUIM)	210	46	25	184	100	63	50	18	18	32
Royal College of Surgeons in Ireland (RCSI)	145	25	10	172	68	32	36	34	8	30
Dublin IT (DIT)	74	16	3	56	32	25	7	19	6	11
Dublin Institute for Advanced Studies (DIAS)	115	9	1	100	150	105	20	19	4	13
Other Irish HE institutions	119	18	4	107	27	24	9	8	8	20
Queens University Belfast (QUB)	2071	436	123	1145	473	402	213	206	281	138
University of Ulster (UU)	573	162	55	236	90	88	65	52	71	23

Data & analysis: Evidence, Thomson Reuters

Commentary

The international links of individual institutions provide some contrasting patterns which suggest specific stimuli rather than simple 'pro rata' opportunities. For example, QUB appears to have strong links with other UK regions while UCD has more collaboration with mainland Europe. There are similar volumes with the USA. TCD has more activity with Australia and Japan than does UCD, while the latter has many more links with Netherlands and China. NUIM's links to China and DIAS's links to Germany are also noticeable.

Many of the smaller institutions also have substantial levels of collaboration with the USA and this clearly underpins the national pattern. The USA total is often as large as France and Germany combined. This provides potential access to a fantastic range of resources and intellectual networks and is likely to be well repaid. It should be strongly promoted. For China, however, the level of collaboration is still low, especially compared to the links established by Northern Ireland. This must be an important policy target because a focus to the East is likely to be obligatory for future global knowledge networks.

3.03 Collaboration between HE institutions in all research fields

Table 3.03 Collaboration between HE institutions, number of papers (10-year total)

	UCD	TCD	UCC	NUI Galway	DCU	Limerick	NUI Maynooth	RCS Ireland	Dublin IT	DIAS	Other	QUB	Ulster
University College Dublin (UCD)	7371	225	112	116	110	37	101	85	63	42	113	86	57
Trinity College Dublin (TCD)	225	6457	91	56	119	27	52	144	112	16	32	136	56
University College Cork (UCC)	112	91	5375	42	42	52	18	24	21	0	79	43	37
NUI Galway (NUIG)	116	56	42	2757	17	20	32	14	4	3	82	31	11
Dublin City University (DCU)	110	119	42	17	2128	15	30	9	39	16	32	64	6
University of Limerick (UL)	37	27	52	20	15	1649	0	1	5	1	44	13	6
NUI Maynooth (NUIM)	101	52	18	32	30	0	1272	1	39	71	16	29	9
Royal College of Surgeons in Ireland (RCSI)	85	144	24	14	9	1	1	1084	46	0	1	23	7
Dublin IT (DIT)	63	112	21	4	39	5	39	46	779	3	19	15	29
Dublin Institute for Advanced Studies (DIAS)	42	16	0	3	16	1	71	0	3	568	5	2	0
Other Irish HE institutions	93	32	75	66	31	44	16	1	19	5	896	20	9
Queens University Belfast (QUB)	86	136	43	31	64	13	29	23	15	2	20	9901	422
University of Ulster (UU)	57	56	37	11	6	6	9	7	29	0	9	422	3766

Data & analysis: Evidence, Thomson Reuters

Commentary

The main diagonal in the table indicates the total output of each HEI with which the collaboration volume may be compared. It is immediately evident that the proportion of output that is collaborative is relatively small. Collaboration between Ireland and Northern Ireland is noticeably low, that with QUB being around just 1% of output for UCD and about 2% of output for TCD. Collaboration between QUB and UL is over 10% of the latter's activity and 4% of that for QUB. This should be compared with the collaboration between TCD and UCD, which is less than 3%.

However, TCD's collaboration with RCSI and with DIT is more significant for those institutions while UCD's links with NUIG and NUIM also stand as relative concentrations. Given the spread of activity across institutions and the inevitable demand for resources, these data suggest that there is much latent potential for collaboration that could be usefully fostered, for example via networks to link smaller institutions into main centres.
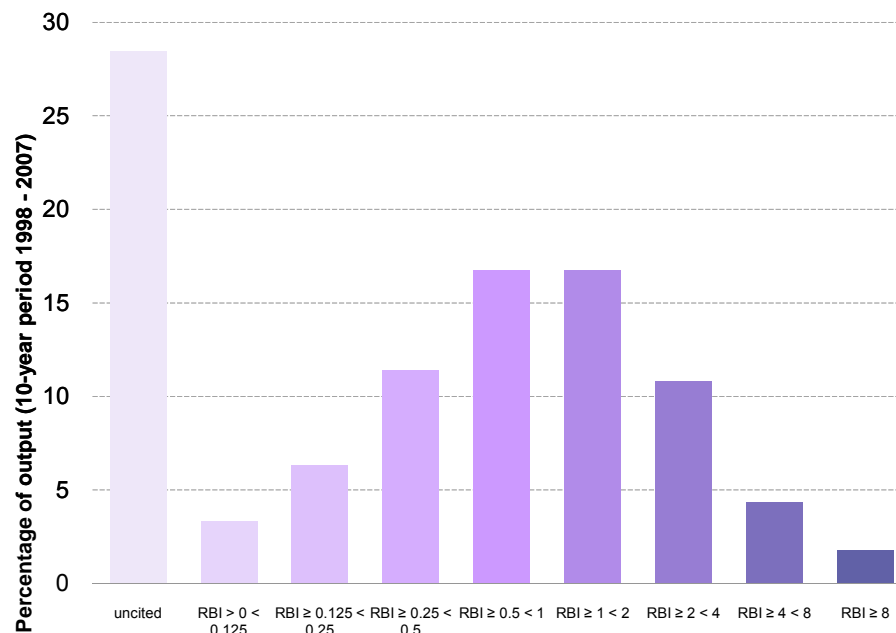
4.01 Impact Profile® in all research fields

Table 4.01 Ireland output over 10-year period

Ireland: 34648 articles and reviews in all research fields

Percentage of output above world average	33.7%
Percentage of output which is highly-cited (cited at least four times world average, RBI ≥ 4)	6.2%
Percentage of output uncited	28.5%

Chart 4.01 Impact Profile® in all research fields

Commentary

The distribution of impact by category relative to world average (global average adjusted for year and field [RBI] = 1.0) reveals an appealingly bell-shaped curve, once uncited papers are removed. The most commonly cited group (between 1-2 times world average) is very similar in volume to the neighbouring group of slightly lower impact between 0.5-1 times world average. This pattern is typical at national level for research active economies. It compares directly to the most commonly cited groups for the USA, whereas for the UK the fractionally more common group is the lower impact one at 0.5-1 times world average.

The percentage of uncited papers is somewhat higher than the range for G7 countries (20-25%) but is markedly less than world average (35% for a ten-year period). The percentage above world average is consequently slightly lower than some other countries, where the USA leads at 37%. The most important factor, however, may be less the detailed spread and more that part of the distribution concentrated at the highly-cited end where output has high academic impact that may lead to social and economic impact. While the Irish balance, at 6.2%, is behind the USA (6.8%) it is ahead of the UK (6.07%). This is a powerful overall contribution to the global research base and, given the relative Ireland research volume, suggests that the top end of Irish research is well recognised internationally.
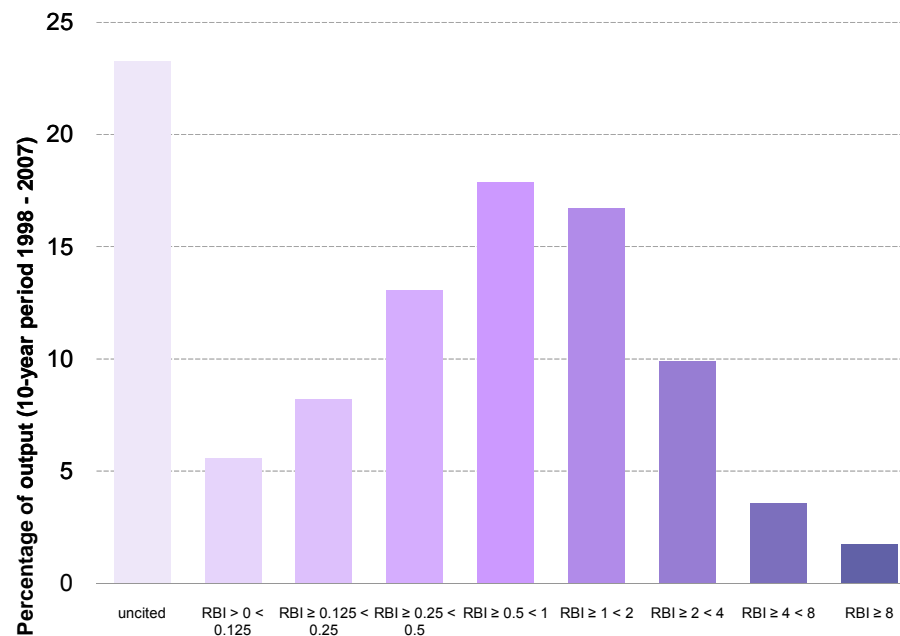
Table 4.02.01 Clinical medicine output over 10-year period

Chart 4.02.01 Impact Profile® in clinical medicine

Ireland: 7525 articles and reviews in project research area - clinical medicine

Percentage of output above world average	31.9%
Percentage of output which is highly-cited (cited at least four times world average, RBI ≥ 4)	5.3%
Percentage of output uncited	23.3%

Data & analysis: Evidence, Thomson Reuters

Data & analysis: Evidence, Thomson Reuters

Commentary

Clinical medicine is a research area of substantial activity globally and Ireland's research has a rising average impact above world average. Research outputs in this area have a lower percentage of uncited papers than the research base generally (23.3% cf 28.5%) but the percentage above world average and the percentage that is relatively highly cited is slightly below the pattern for the research base as a whole.

The profile follows a pattern that is slightly left-shifted (towards the lower impact categories) compared to the Ireland research base overall. The category just below world average (0.5-1.0) is clearly the modal group. In other respects the pattern is very straightforward. Each of the categories above world average is slightly less common than in the research base generally while each of those below is more frequent. The percentage cited but below world average is influenced by the low relative percentage of uncited papers. It is likely that Ireland's average performance is strongly influenced by the relatively small number of papers in the most highly-cited category (more than 8 times world average).

Table 4.02.02 Biological sciences, molecular & cellular biology output over 10-year period

Ireland: 3862 articles and reviews in project research area - biological sciences, molecular & cellular biology

Percentage of output above world average	36.1%
Percentage of output which is highly-cited (cited at least four times world average, RBI ≥ 4)	5.2%
Percentage of output uncited	16.6%

Data & analysis: Evidence, Thomson Reuters

Chart 4.02.02 Impact Profile® in biological sciences, molecular & cellular biology
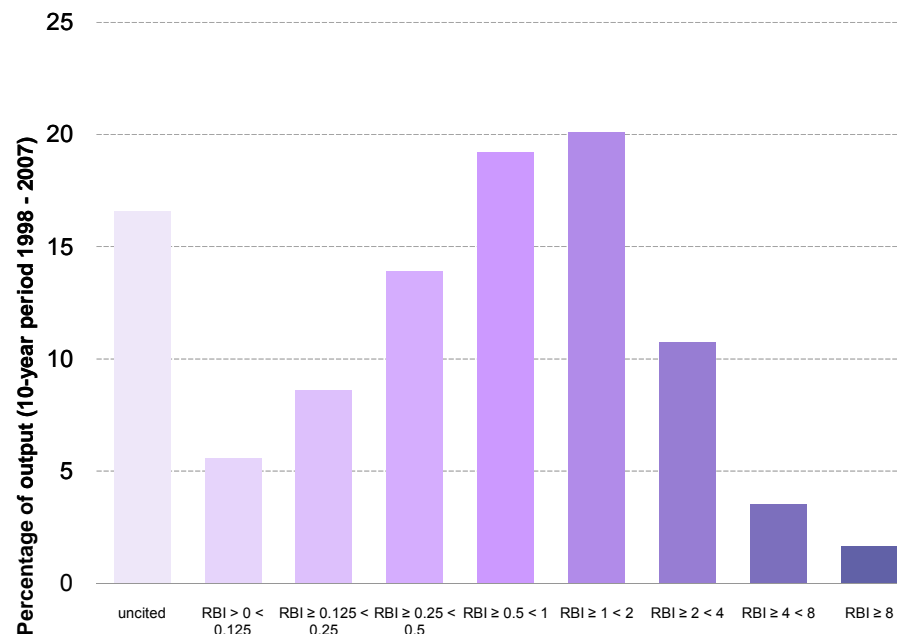
Data & analysis: Evidence, Thomson Reuters

Commentary

Molecular biology is an area of major investment for most research economies. It is thus an area of intense international competition and innovation at research and exploitation levels. Ireland's impact has been historically good but has slipped in the face of this competition. Nonetheless, it has a low percentage of uncited papers and a high percentage of output that is above world average impact (36.1% cf 33.7% for the Ireland research base as a whole). However, the percentage that is relatively highly cited is less than that for the overall research base.

The modal group in this research area is clearly above world average (1-2 times world average) and the percentage in the next group (2-4 times world) is typical of the research base as a whole. Given this strong platform, Ireland's relative slip in global competition is likely to be due to a relative paucity of papers in the most highly cited categories. In other words, Ireland has a potentially strong research base but seems not to be breaking sufficiently strongly into the peak of global excellence.

# 4.02.03 Impact Profile® in project research area - biotechnology

Table 4.02.03 Biotechnology output over 10-year period

Chart 4.02.03 Impact Profile® in biotechnology

Ireland: 1780 articles and reviews in project research area - biotechnology

Percentage of output above world average	35.9%
Percentage of output which is highly-cited (cited at least four times world average, RBI ≥ 4)	4.5%
Percentage of output uncited	23.8%

Data & analysis: Evidence, Thomson Reuters
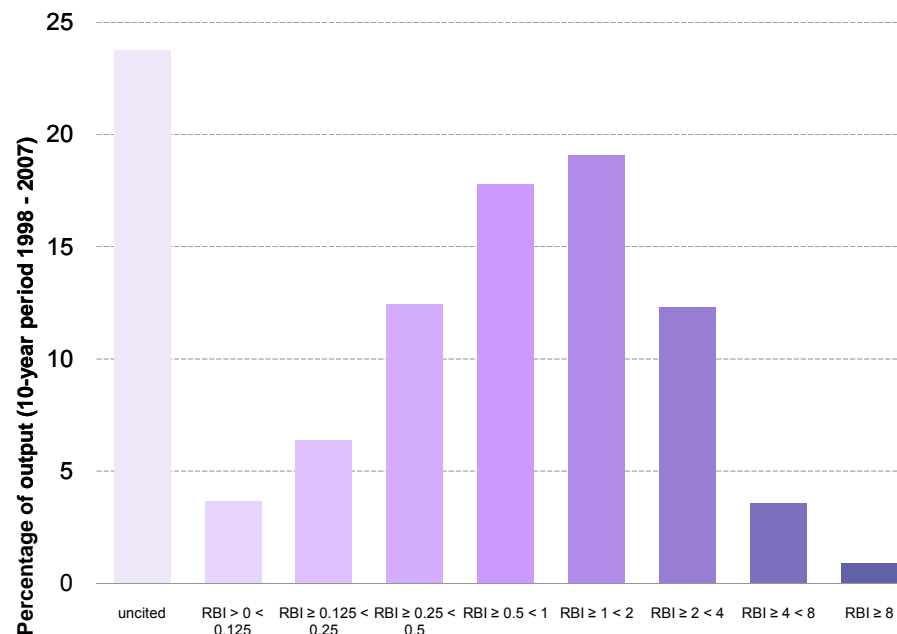
Data & analysis: Evidence, Thomson Reuters

Commentary

Ireland's research performance in biotechnology (which must be seen as having generic application to multiple industrial sectors) has been good in the recent past but has declined somewhat. The analysis here shows, compared to Ireland's research base overall, a lower percentage of uncited papers and a higher percentage of papers above world average (35.9% cf 33.7% overall). The percentage of papers that are relatively highly cited (more than 4 times world average) is lower than is typical (4.5% cf 6.2%). This latter may well be a significant factor, since there are likely to be relatively fewer papers of really high impact.

The profile shows a steep dip from the modal group, which is above world average (1-2 times world average). The profile thus appears slightly unbalanced with a skew towards the lower impact categories, due to a deficit in the high impact area compared to the modal group. As in molecular biology, there seems to be a strong platform of good research around and above world average but this is not being translated into a sufficient body of research of relatively high impact that would lift the Irish average. Indeed, the percentage that is above 8 times world average is less than 1% of the total.

Table 4.02.04 Physics and materials sciences output over 10-year period

Ireland: 5249 articles and reviews in project research area - physics and materials sciences

Percentage of output above world average	33.6%
Percentage of output which is highly-cited (cited at least four times world average, RBI ≥ 4)	5.9%
Percentage of output uncited	27.1%

Data & analysis: Evidence, Thomson Reuters

Chart 4.02.04 Impact Profile® in physics and materials sciences
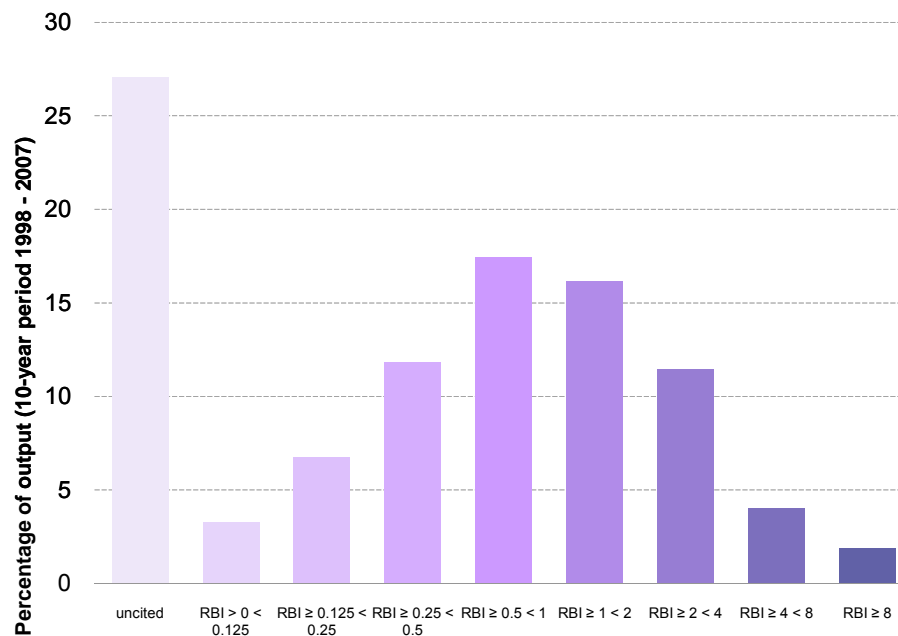
Data & analysis: Evidence, Thomson Reuters

Commentary

Ireland's research performance in physics closely follows the overall average for the research base, but the average Ireland impact is high relative to world average. The percentage of uncited papers is less than the national average (27.1% cf 28.5%) but the percentage above world average is almost the same as the overall pattern, while the percentage in relatively high impact categories (more than 4 times world average) is just slightly lower than the rest of the research base.

The modal group in the profile is that just below world average (0.5-1 times world average) which is probably accounted for by a shift of papers from uncited into low cited categories by comparison with the overall national profile. Given the high national average impact, the pattern suggests that there is a significant effect from the papers in the highest impact categories and these are pulling the national average impact up in physics compared to the rest of the research base. This is likely to be due to a small number of extremely effective research groups which could be identified by drilling into the most highly cited categories and identifying author affiliations.

Table 4.02.05 Electrical, electronic and information engineering output over 10-year period

Ireland: 1744 articles and reviews in project research area - electrical, electronic and information engineering

Percentage of output above world average	29.8%
Percentage of output which is highly-cited (cited at least four times world average, RBI ≥ 4)	6.5%
Percentage of output uncited	40.3%

Data & analysis: Evidence, Thomson Reuters

Chart 4.02.05 Impact Profile® in electrical, electronic and information engineering
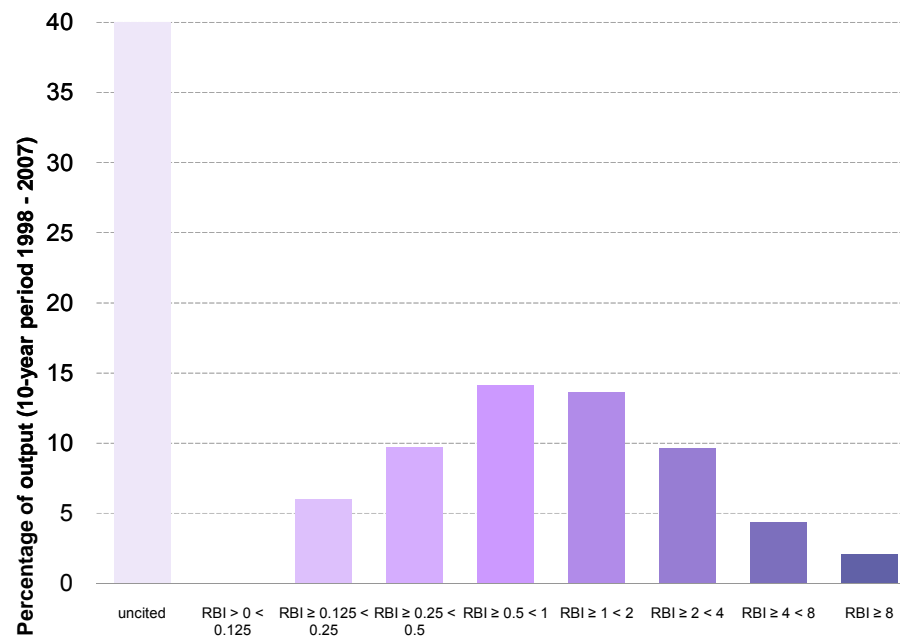
Data & analysis: Evidence, Thomson Reuters

Commentary

Although Ireland has a smaller percentage of its electrical engineering papers above world average than is expected for the research base as a whole, the percentage which are relatively highly cited (more than 4 times world average) is higher than in other subjects. This suggests that there is a peak of exceptional performance. It is the case in other jurisdictions that there is a significant 'network' of applied engineering research that produces only a modest output of work of high academic impact but which nonetheless has regional economic impact. The high percentage of uncited work is also typical of the discipline.
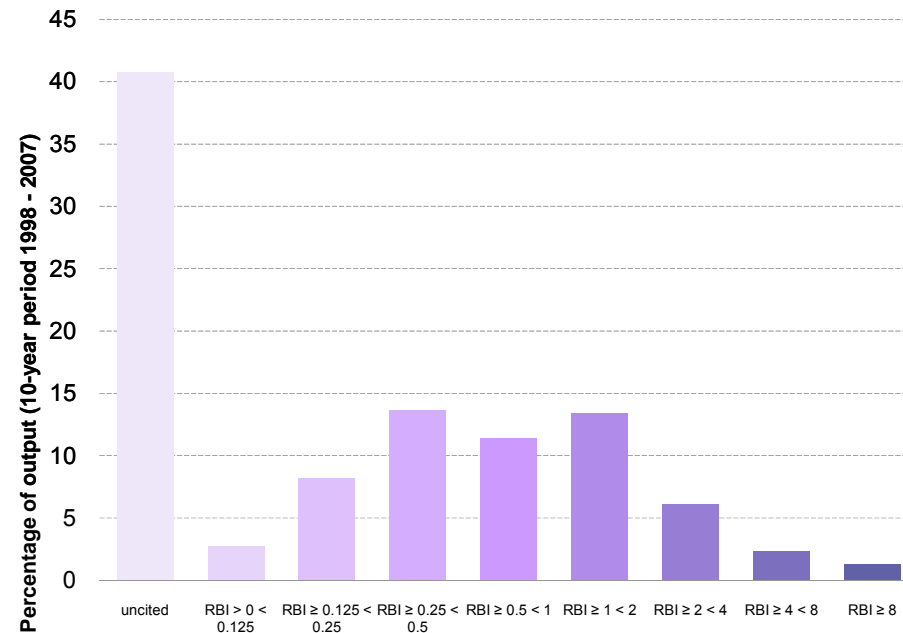
The percentage of uncited work (40.3% cf 28.5% Ireland average) is exceptional but is not atypical of engineering elsewhere in Europe. Indeed, in the UK the percentage uncited is well over 40%. What is also noticeable is the percentage which is cited well below world average. Such papers are scarce here, suggesting that when work is cited it tends to attract attention. However, although this shifts the distribution towards the right, the percentage above world average is low and the mode is below world average (0.5-1 times world). Overall, the impression is of a marked but very narrow peak of excellence.

e v i d e n c e

Table 4.02.06 Economics and business output over 10-year period

Chart 4.02.06 Impact Profile® in economics and business

Ireland: 768 articles and reviews in project research area - economics and business

Percentage of output above world average	23.2%
Percentage of output which is highly-cited (cited at least four times world average, RBI ≥ 4)	3.6%
Percentage of output uncited	40.8%

Data & analysis: Evidence, Thomson Reuters

Data & analysis: Evidence, Thomson Reuters

Commentary

The proportion of uncited papers in economic and business is relatively high (40.8% cf 28.5% average for Ireland), the percentage above world average is markedly lower than elsewhere and the percentage that is relatively highly cited is not much more than half the Ireland average (3.6% cf 6.2%). This does not suggest that research in this area is currently strong in Ireland. However, there has been a significant shift in preferred publication mode in this field in other jurisdictions. The volume of journal outputs across Europe has expanded as the research paradigm has shifted towards a US model. Ireland may need to track this change.

The distribution is very unusual. Experience across many subject analyses in different jurisdictions has been that most Impact Profiles(R) are unimodal: they have one most common category. This is not so in this case. There are two modal groups, one above world average and one well below. This almost certainly indicates a separation between a small number of leading research groups (see 2.02.9) and a platform of much more modest research that may be both regional and have a different publishing approach. It would be appropriate to extract the more highly cited papers to analyse the affiliations of the authors and compare these with the less well-cited modal group (0.25-0.5 times world average).