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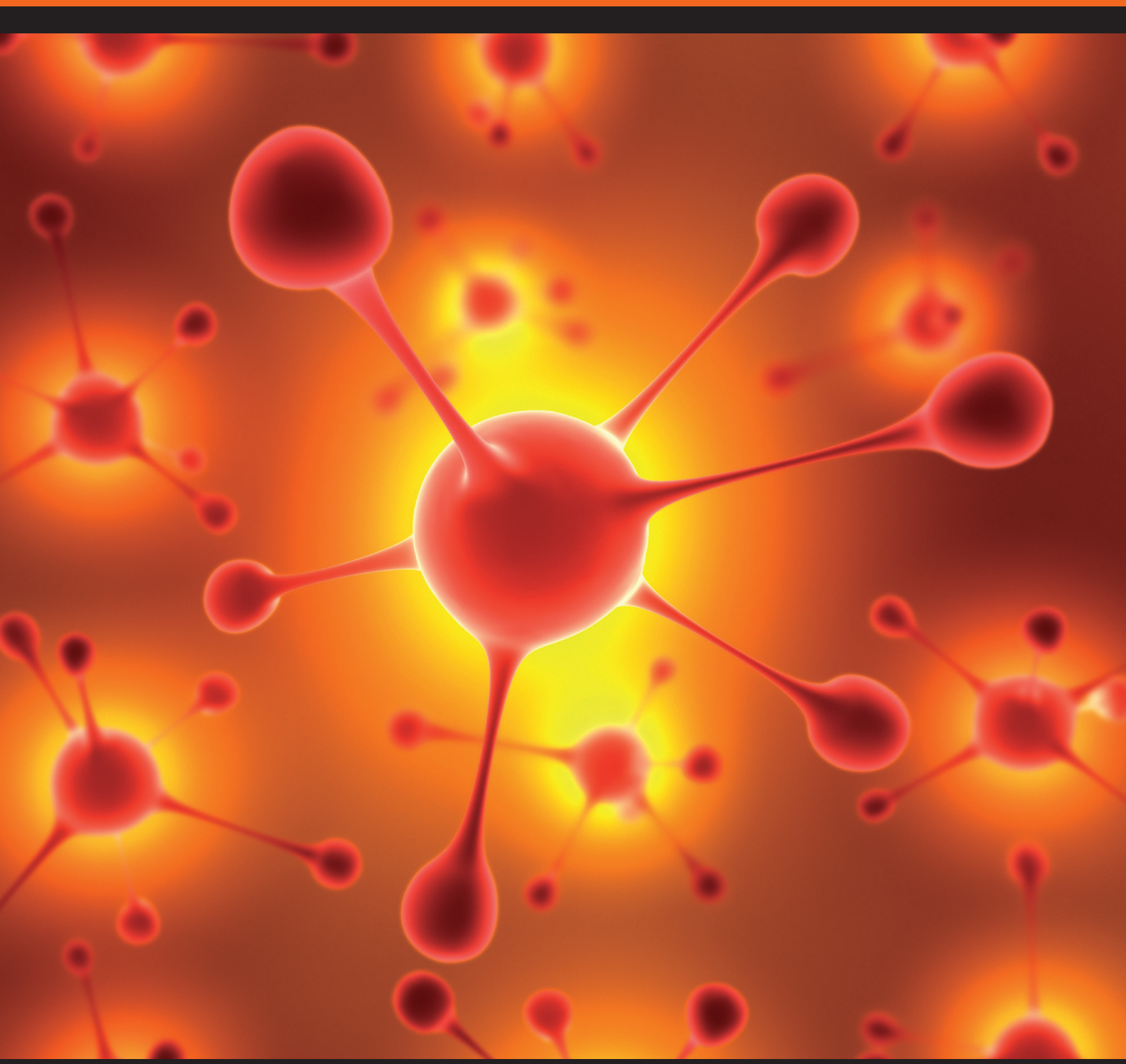
Bibliometric evaluation and international benchmarking of the UK's physics research

Summary report prepared for the Institute of Physics by *Evidence*, Thomson Reuters



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1 Introduction

This report analyses the performance of UK Physics research. It was commissioned by the Institute of Physics (IOP) from *Evidence*, a business of Thomson Reuters. The report complements a more detailed IOP study of UK research in the sub-disciplines that make up Physics (**Bibliometric evaluation and international benchmarking of the UK's Physics research: Physics and sub-disciplines** (2012), *Evidence*), which is available on request from Tajinder Panesor at IOP (tajinder.panesor@iop.org). The study was commissioned to provide IOP with data it can use for the development of policy and to contribute to its wider discussions with stakeholders.

This report shows that:

- The UK's share of world Physics papers fell slightly from 7.1% in 2001 to 6.4% in 2010. However, its output in absolute terms increased from 5,484 in 2001 to 6,240 in 2010. This growth has been at a lower rate (13.8%) than the growth in world output (25.9%), resulting in the observed decrease in share. Therefore, the fall in UK share should not be interpreted as a decline in overall capacity (Section 2).
- The fall in the UK's share of world Physics papers has been slower than in the other mathematical and physical science subjects analysed – except Space Science (Section 2).
- The UK's rank among the comparator countries has not been affected by its falling share of world Physics papers (Section 3).
- There has been a rapid expansion in the output of some countries – particularly in Asia (Section 3).
- China's share of world Physics papers has increased from 8.2% in 2001 to 18.6% in 2010. It is second (behind the USA) among the comparator countries (Section 3).
- The citation impact of the UK's Physics research, relative to world average, has increased from 1.24 in 2001 to 1.72 in 2010, overtaking the USA (Section 3).
- The citation impact of the G7 comparators has also increased and generally exceeds the world average, while the citation impact of the BRICK countries has been generally below the world average (Section 3).
- The distribution of citation impact underlying the UK's performance has shifted, with a decrease in the percentage of uncited papers and an increase in the percentage of papers receiving more citations than the world average (Section 4).

In general the UK's Physics research base is performing strongly. However, there are other countries that perform just as well and some that are undergoing rapid expansion. This means that if the UK wishes to remain globally competitive it will need to maintain both research output and quality.

Some BRICK countries (defined in the Appendix) already produce significant amounts of high quality research (**Bibliometric study of India's research output and international collaboration** (2010), *Evidence*), (**Bibliometric study of Chinese research and international collaboration** (2011), *Evidence*). While these countries have recently increased their research

resourcing to grow their capacity, eventually this expansion will slow and it seems likely that they will then focus on improving research quality in order to maximise social and economic returns.

As well as increasing competition, the expansion in the output of some countries provides increased opportunities for international collaboration. Such collaborations allow participants to leverage resources and expertise that would otherwise be unavailable. As capacity and expertise build in the countries currently undergoing rapid expansion in activity, they will become increasingly selective in choosing partners and will become, at least to some extent, more self-sufficient. Therefore, in order to remain an attractive partner, the UK cannot be complacent and needs to continue to support adequately its capacity to produce excellent research.

In addition, our analysis of the UK's research in Physics sub-disciplines (**Bibliometric evaluation and international benchmarking of the UK's Physics research: Physics and sub-disciplines** (2012), *Evidence*) shows that UK capacity to produce excellent research is at greater risk in some areas than in others. In the past, the UK Research Assessment Exercises have resulted in resources becoming increasingly concentrated in those units performing the best research, and resulted in the poorest research being cut. This has meant that in many fields the UK continues to produce a substantial level of increasingly high quality output. There are, however, fields where UK citation impact is relatively high and rising but world share is relatively low and falling. In these cases it seems unlikely that continued improvement in citation impact can be maintained unless the fall in share is addressed.

These observations, coupled with government spending cuts, mean that the UK needs to carefully consider how best to allocate resources to maintain competitiveness and capacity in its Physics research base. Future innovative products and services are likely to result from curiosity-driven research, the application of which is difficult to predict.

2 Physics research compared to other fields in the UK

The UK's Physics research output and its citation impact can be compared with Chemistry, Engineering, Mathematics and Space Science. Many UK Physicists are engaged in Space Science research. The two fields are, however, treated separately in this report because Space Science is a multidisciplinary field involving researchers from across the domains of science and engineering.

Data are analysed for the period 2001 to 2010 to capture changes in the UK's relative performance.

Other studies (for example, our report to the Department for Business, Innovation and Skills, (**International comparative performance of the UK research base** (2009), *Evidence*)) inform us that Mathematical and Physical Sciences are fields where the UK's citation impact ranks amongst the best worldwide although they are less dominant globally than in the biomedical sciences.

UK Physics performs well compared to other fields. The UK's output of Physics papers has grown in absolute terms from 5,484 in 2001 to 6,240 in 2010, but this has been at a lower rate (13.8%) than the world average (25.9%). This increase in the world output of Physics papers has resulted in a decline in the UK's share, which fell slightly from 7.1% in 2001 to 6.4% in 2010. Because of the background dynamics, this fall in UK share should not be interpreted as a decline in overall capacity.

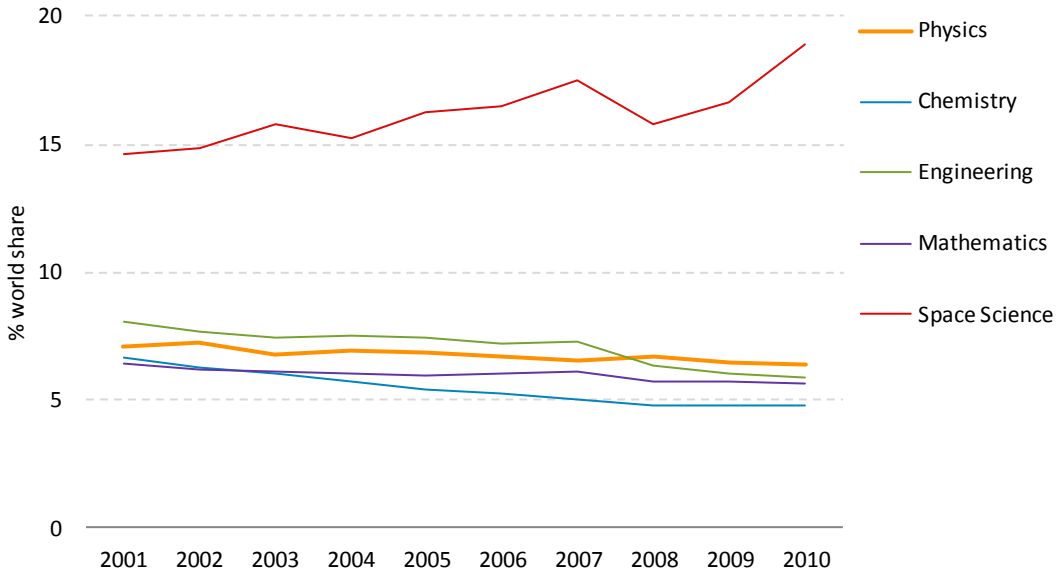
The UK's share of world output declined more rapidly in Chemistry, Engineering and Mathematics. Over the same period, the UK's share of world Space Science papers increased by around a quarter (Table 2.1 and Figure 2.1).

The citation impact of UK Physics research increased from 1.24 to 1.72, relative to the world average, between 2001 and 2010. The citation impact of UK's research in the other subjects analysed (except for Mathematics) also increased. The relative rate of increase was greatest in Physics (Table 2.2 and Figure 2.2).

Table 2.1 UK percentage share of world papers in Physics and comparator fields (2001-2010)

Field	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Physics	7.1	7.2	6.8	6.9	6.9	6.7	6.5	6.7	6.4	6.4
Chemistry	6.6	6.3	6.1	5.8	5.4	5.3	5.0	4.8	4.8	4.8
Engineering	8.1	7.7	7.4	7.5	7.4	7.2	7.3	6.3	6.0	5.9
Mathematics	6.4	6.2	6.1	6.1	6.0	6.0	6.1	5.7	5.7	5.7
Space Science	14.6	14.8	15.8	15.3	16.3	16.5	17.5	15.8	16.6	18.9

Figure 2.1 UK share of world papers in Physics and comparator fields (2001-2010)

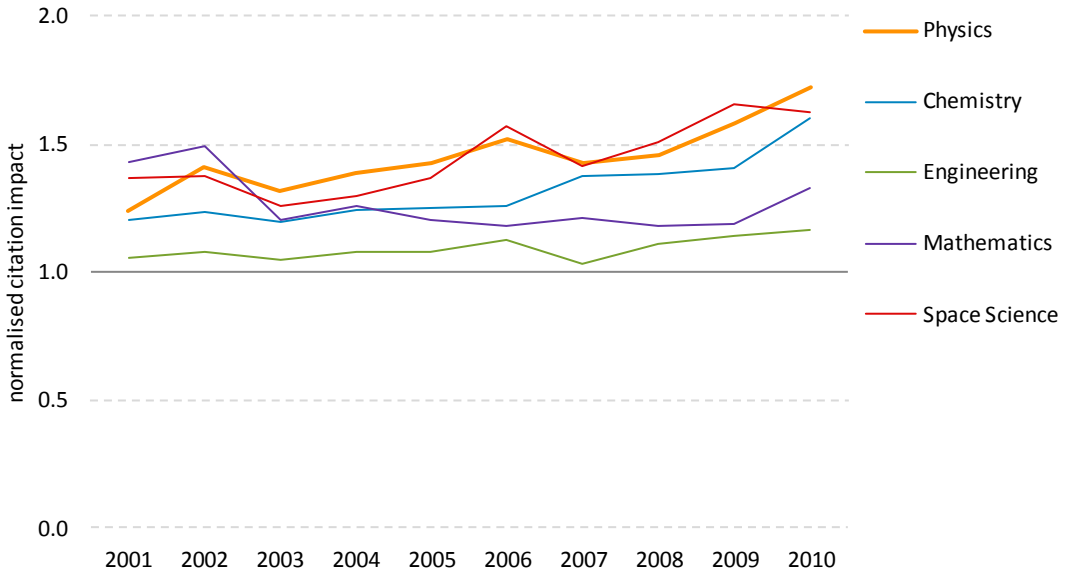


Data & analysis: *Evidence*, Thomson Reuters

Table 2.2 Citation impact of UK papers in Physics and comparator fields (2001-2010)

Field	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Physics	1.24	1.41	1.32	1.39	1.43	1.52	1.43	1.46	1.58	1.72
Chemistry	1.20	1.24	1.19	1.24	1.25	1.26	1.37	1.38	1.40	1.60
Engineering	1.05	1.08	1.05	1.08	1.08	1.12	1.03	1.11	1.14	1.17
Mathematics	1.43	1.49	1.21	1.26	1.20	1.18	1.21	1.18	1.19	1.33
Space Science	1.37	1.37	1.26	1.30	1.37	1.57	1.41	1.50	1.66	1.62

Figure 2.2 Citation impact of UK papers in Physics and comparator fields (2001-2010)



Data & analysis: *Evidence*, Thomson Reuters

3 International benchmarking of UK Physics research

UK research output and citation impact in Physics can be compared with that of other countries (detailed in the Appendix).

As noted in Section 2, the UK's share of world Physics papers has fallen. This is due to changes in the global dynamic rather than a decrease in UK capacity. The share of most G7 comparators also fell over the same period (Table 3.1 and Figure 3.1a), as did that of Russia and Brazil (Table 3.1 and Figure 3.1b). By contrast Canada, South Korea, India and China's share of world Physics papers increased. China's growth has been exceptional, more than doubling research output between 2001 and 2010; its world share increased from 8.2% in 2001 to 18.6% in 2010.

The USA (data not shown for the reasons discussed in the Appendix) dominates Physics research, producing between a fifth and a quarter of world Physics papers although this declined from 25.0% in 2001 to 22.0% 2010. This figure is relatively low, however, given that the US share of world output across all fields between 2001 and 2010 exceeded 30%.

The normalised citation impact of UK Physics papers increased from 1.24 in 2001 to 1.72 in 2010 (Table 3.2, and Figures 3.2a and 3.2b), overtaking the USA and substantially ahead of the BRICK countries. This was amongst the largest relative increase amongst both groups of comparators (around 40%). In general, the G7 countries have a citation impact of around or better than world average, and the BRICK countries have a citation impact below world average. Only Canada increased both its share of world Physics papers and the citation impact of its Physics research.

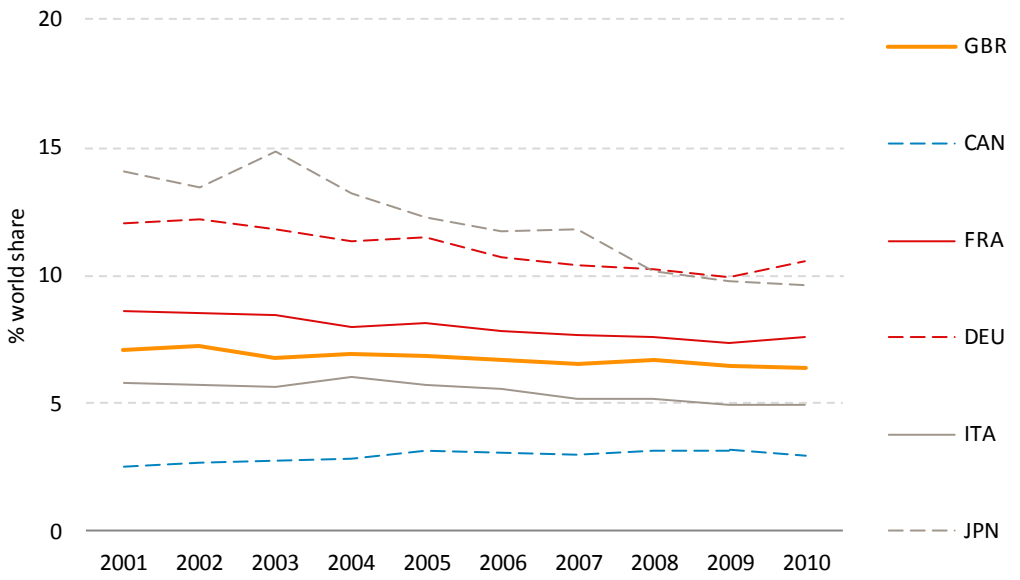
Table 3.1 Percentage share of world Physics papers – UK and comparator countries (2001-2010)

Country	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
UK	7.1	7.2	6.8	6.9	6.9	6.7	6.5	6.7	6.4	6.4
USA	25.0	24.4	24.2	24.2	24.8	23.5	22.7	22.4	21.6	22.0
Canada	2.5	2.7	2.7	2.8	3.1	3.0	3.0	3.1	3.2	3.0
France	8.6	8.5	8.4	8.0	8.1	7.9	7.7	7.6	7.3	7.6
Germany	12.0	12.2	11.8	11.3	11.5	10.7	10.4	10.2	10.0	10.5
Italy	5.8	5.8	5.7	6.0	5.7	5.6	5.2	5.1	4.9	5.0
Japan	14.0	13.4	14.9	13.2	12.3	11.7	11.8	10.2	9.8	9.6
Brazil	2.6	2.4	2.1	2.6	2.2	2.3	2.1	2.4	2.0	2.0
Russia	9.5	9.6	8.8	8.3	7.6	7.2	7.2	6.9	7.8	7.3
India	3.0	3.1	3.1	3.4	3.4	3.7	3.8	4.1	4.4	4.6
China	8.2	8.7	9.3	10.9	12.4	14.0	15.7	17.0	18.5	18.6
South Korea	3.4	3.7	4.1	4.4	4.1	4.3	4.6	4.6	4.8	4.8

Table 3.2 Citation impact of Physics papers – UK and comparator countries (2001-2010)

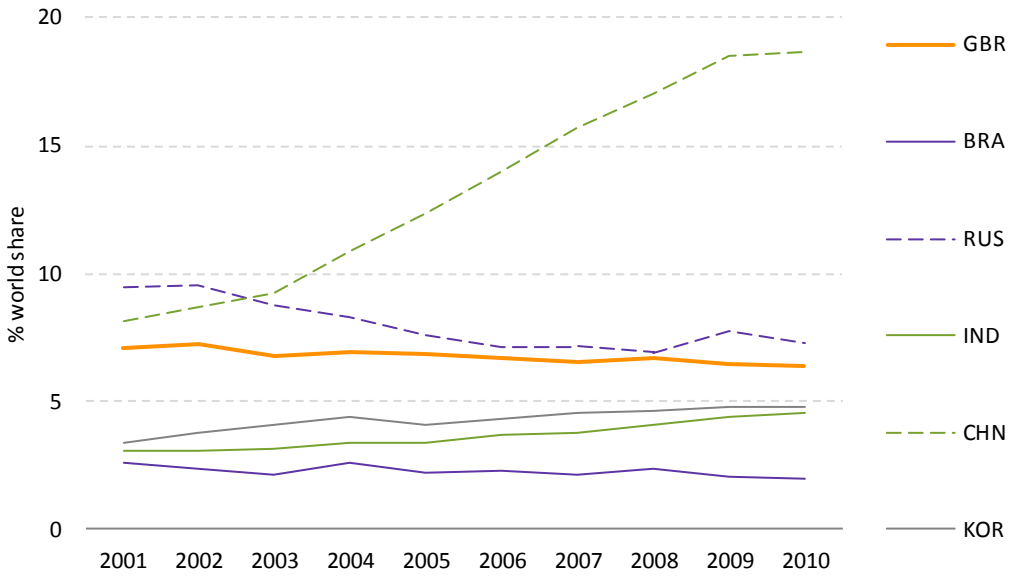
Country	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
UK	1.24	1.41	1.32	1.39	1.43	1.52	1.43	1.46	1.58	1.72
USA	1.58	1.56	1.57	1.60	1.47	1.51	1.48	1.58	1.57	1.60
Canada	1.28	1.38	1.27	1.42	1.32	1.41	1.32	1.54	1.46	1.75
France	1.15	1.17	1.10	1.25	1.17	1.31	1.22	1.30	1.27	1.39
Germany	1.28	1.36	1.24	1.35	1.35	1.42	1.44	1.51	1.53	1.62
Italy	1.08	1.24	1.04	1.09	1.11	1.20	1.14	1.27	1.33	1.44
Japan	0.95	0.90	0.88	0.95	0.96	1.00	0.94	1.06	1.04	1.09
Brazil	0.71	0.81	0.91	0.75	0.96	0.82	0.91	0.79	0.87	1.10
Russia	0.67	0.70	0.66	0.81	0.81	0.81	0.76	0.77	0.70	0.70
India	0.76	0.85	0.86	0.83	0.85	0.83	0.84	0.91	0.77	0.75
China	0.66	0.70	0.82	0.82	0.83	0.85	0.84	0.88	0.84	0.66
South Korea	0.82	0.92	0.82	0.91	0.84	0.89	0.93	0.93	0.80	0.79

Figure 3.1a Share of world Physics papers – UK and G7 comparators (2001-2010)



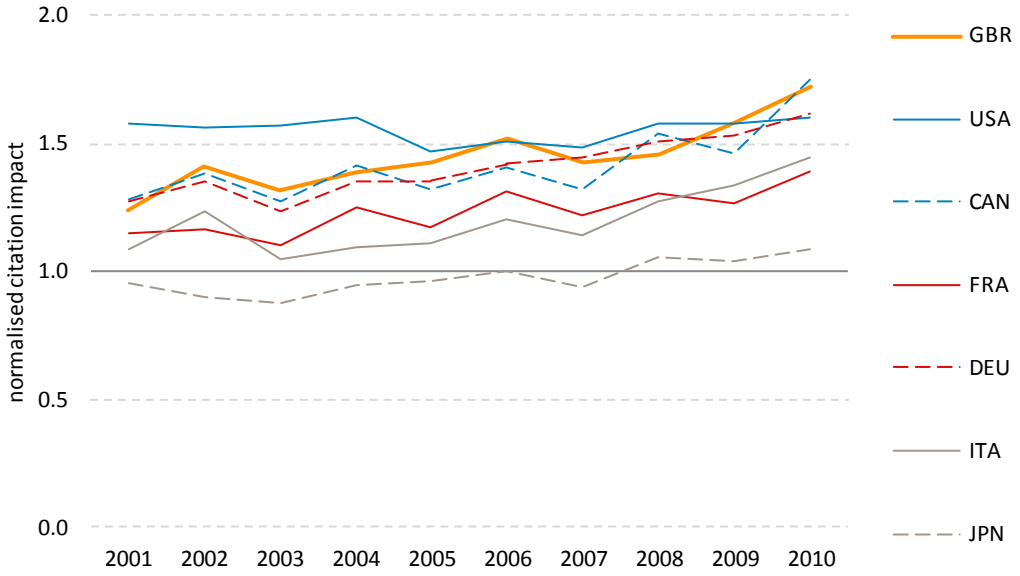
Data & analysis: *Evidence*, Thomson Reuters

Figure 3.1b Share of world Physics papers – UK and BRICK comparators (2001-2010)



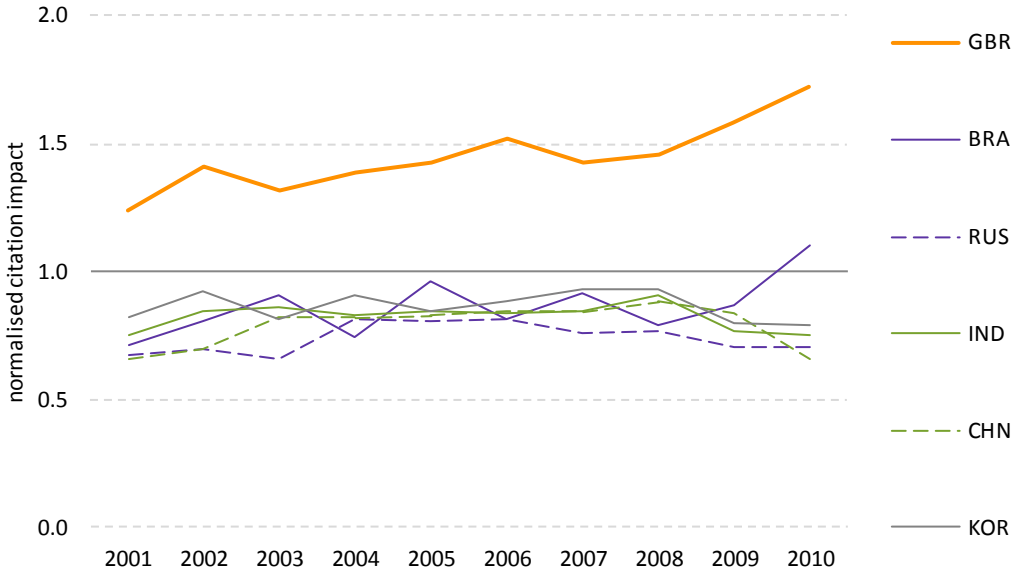
Data & analysis: *Evidence*, Thomson Reuters

Figure 3.2a Citation impact of Physics papers – UK and G7 comparators (2001-2010)



Data & analysis: *Evidence*, Thomson Reuters

Figure 3.2b Citation impact of Physics papers – UK and BRICK comparators (2001-2010)



Data & analysis: *Evidence*, Thomson Reuters

4 *Impact Profile®* analysis of UK Physics research

Average field normalised citation impact (nci) is a useful indicator of research quality; however, it does not describe the underlying distribution of citation impact. An *Impact Profile®* visualises a citation impact distribution.

Physics data have been analysed for two five-year windows – 2001-2005 and 2006-2010 – allowing changes over time to be examined (Figure 4.1). To enable meaningful comparisons between these windows citations accrued by papers published in each window are counted to the final year (not 2011). Thus, the 2001-2005 analysis includes citations to end-2005 for papers published in 2001-2005 and the 2006-2010 analysis covers citations to end-2010 for papers published in 2006-2010.

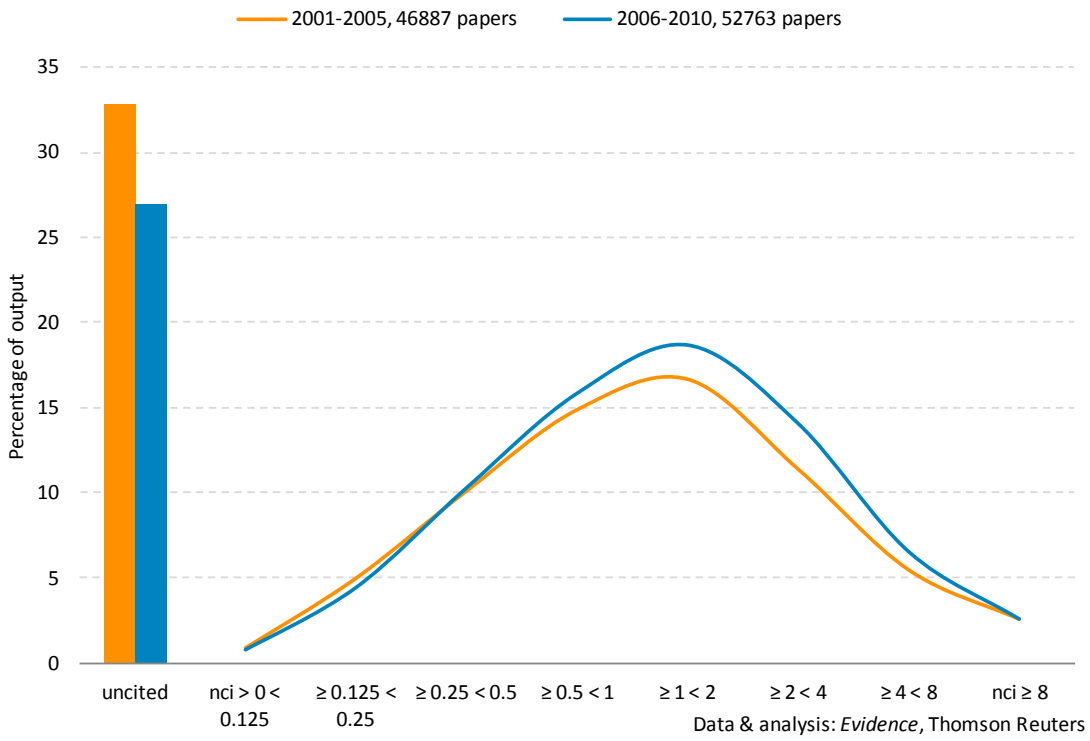
Papers are not always cited immediately after publication. The use of five-year citation windows means that the percentage of papers that remain uncited within the window will be higher than would be expected if a longer time-window (i.e. 10-years) were used.

The UK's Physics research performance improved between the 2001-2005 and 2006-2010 windows:

- The percentage of papers that were uncited at the end of the five-year windows decreased from 32.9% in 2001-2005 to 26.9% in 2006-2010.
- The percentage of cited papers receiving fewer than the world average number of citations increased very slightly from 30.9% in 2001-2005 to 31.2% in 2006-2010.
- The percentage of papers receiving at least the world average number of citations increased from 36.2% in 2001-2005 to 41.8% in 2006-2010.
- The percentage of highly cited papers receiving at least four times the world average number of citations also increased, from 8.1% in 2001-2005 to 9.1% in 2006-2010.

This improvement in UK performance is consistent with the increase in average citation impact shown in Figures 3.2a and 3.2b.

Figure 4.1 *Impact Profile*® of UK Physics research (2001-2005 and 2006-2010)



Appendix – Methodology

This section outlines the key concepts and methodology underpinning the analyses described in this report. The bibliometric methodology used in these analyses is described fully in the detailed sub-discipline study, also commissioned by IOP from *Evidence*, Thomson Reuters (**Bibliometric evaluation and international benchmarking of the UK's Physics research: Physics and sub-disciplines** (2012), *Evidence*).

Subject coverage

This is a report about UK 'Physics research', not about the work of Physics researchers. Thomson Reuters *Essential Science Indicators®* (*ESI*) uses 23 fields to aggregate cognate journals. Where 'Physics' is referred to in bibliometric analyses, this is defined by the relevant *ESI* field. Physics researchers may also publish papers in journals in other fields.

Section 2 compares Physics research to Chemistry, Engineering, Mathematics and Space Science. These are also defined by the corresponding *ESI* fields.

Journal articles cite, or refer to, one another. An article that attracts many citations is typically thought of as having higher citation impact, but citation counts grow over time and rates vary by field. Citation impact is normalised, for comparative analyses, at the level of the 254 Thomson Reuters *Web of Knowledge℠* journal categories so as to account for sub-disciplinary variation.[1]

International comparators

The UK's performance is compared in Section 3 to two groups of comparator countries:

- G7 established economies: USA, Canada, France, Germany, Italy and Japan. These benchmark the UK to other well-founded research economies.
- BRICK expanding economies: Brazil, Russia, India, China and (South) Korea. These provide an insight into the potential of new partners and competitors.

[1] All journals indexed by Thomson Reuters are assigned to a journal category that can be used as a proxy for the subject matter of a given paper. Papers in multidisciplinary journals (e.g. *Nature and Science*) are categorised at the paper-level using an algorithm based on the research area(s) of the references cited by the article.

Country names are abbreviated in charts to the three-letter UN standard ISO ALPHA-3 codes,[2] as follows:

Brazil	(BRA)	Italy	(ITA)
Canada	(CAN)	Japan	(JPN)
China	(CHN)	Russia	(RUS)
France	(FRA)	South Korea	(KOR)
Germany	(DEU)	United Kingdom	(GBR)
India	(IND)	United States of America	(USA)

Data sources

Bibliometrics are indicators of research activity and performance based on data about publications and their citations. *Web of Knowledge℠* is widely acknowledged to be the world's leading source of citation and bibliometric data. The authoritative, multidisciplinary content covers over 11,500 of the highest impact journals worldwide, including Open Access journals and over 110,000 conference proceedings. Coverage is both current and retrospective in the sciences, social sciences, arts and humanities, in some cases back to 1900. These data are often still referred to within the research community by the acronym 'ISI'.

Methodology

Papers and publications

The terms 'paper' and 'publication' are often used interchangeably to refer to printed and electronic outputs of many types. Thomson Reuters abstracts publications including editorials, meeting abstracts and book reviews as well as research journal articles.

'Paper' has been used in this report exclusively to refer to substantive journal articles, reviews and some proceedings papers and excludes editorials, meeting abstracts or other types of publication. Papers are the subset of publications for which citation data are most informative and which are used in calculations of citation impact.

Output and world share

Research papers are not the only output of the research process and some fields publish relatively more of other modes of output. Papers are nevertheless universally important. The relative volume of papers produced by an individual, research organisation or country can be used as an indicator of research activity. Because fields vary in size, however, the share of world output is a necessary indicator if comparing fields.

[2] United Nations Statistics Division – Standard Country and Area Codes Classifications; http://unstats.un.org/unsd/methods/m49/m49alpha.htm.

Normalised citation impact (nci)

Citation rates vary between fields and citations accumulate over time. Analyses must, therefore, take these factors into account. The standard normalisation factor is the world average citation count per paper for the year and journal category in which the paper was published. This normalisation is also referred to as 'rebasing' the citation count.

Highly cited papers

Citation data are highly skewed. Relatively more papers receive no or very few citations and very few papers receive many citations. There is no theoretical limit to the number of citations a paper could receive. Therefore, very highly cited papers do occur and these can substantially increase the average citation impact. This effect is particularly exaggerated for countries with relatively low outputs and when disaggregating by fields representing relatively small numbers of papers.

Impact Profiles®

Indicators based on average citation counts are useful for understanding overall performance but do not describe the distribution of citations within a body of work. Therefore, *Impact Profile®* methodology (**Profiling citation impact: A new methodology** (2007), Adams, Gurney and Marshall) was developed to allow a visual comparison of the percentages of output relative to the world average and relative to comparator profiles. This provides much more information about the basis and structure of research performance than conventionally reported averages.

An *Impact Profile®* shows the percentage of papers that are uncited and the percentage that are in each of eight categories of relative citation rates, normalised to world average (which becomes 1.0). Normalised citation rates above 1.0 indicate papers cited more often than the world average in the relevant journal category and year of publication. Information is derived from the percentage of uncited papers, the percentage of cited papers either side of world average, the position of the most common (modal) group, and the percentage of papers in the most highly cited categories (≥ 4 x world, ≥ 8 x world).

Data presentation

UK Physics research is indicated by an orange line or marker in the figures, whilst data for other fields and countries are indicated by a consistent palette throughout the report.

The USA produces a significantly large volume of papers, often 25-45% of the world total, while other G7 countries typically produce less than 15% of the world total. If these data are shown on the same chart, the non-USA countries would be compressed at the bottom thus making interpretation difficult. Data for the USA have therefore been omitted from some figures, but are always commented on in the text.

Expanding global output

Recent studies have noted the rapid research development of some countries. While countries with established research economies have had steady output, the growth of other countries (most notably in Asia) has accelerated, with a rapid increase in total global activity. Consequently, some countries may have increased their output yet simultaneously lost world share of research output. Decreases in share of world papers do not necessarily mean that research capacity has stagnated or decreased.

References

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