EVALUATING THE USAGE AND IMPACT OF E-JOURNALS IN THE UK

HAS WIDER ACCESS TO THE LITERATURE IMPACTED UPON BREADTH OF CITATION?

CIBER WORKING PAPER 2

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Executive summary

This paper explores the `access' hypothesis that enhanced access to the literature, courtesy of convenient desktop access and Big Deals, is likely to have impacted upon referencing behaviour over the period 1990 to the present.

It draws the following conclusions.

1 All six disciplines exhibited strong literature growth over the period 1990-2007 (Table III, p.6). The number of references per paper has increased, at a much faster rate than the number of published articles (history is an exception here: references have increased only slightly more quickly than articles). The increases range from 3% in history to 161% in chemistry and in the earth and environmental sciences (comparing 2007 with 1990).

2 There is a very considerable variation between disciplines with respect to the average number of references per paper and the average number of unique sources consulted (Tables I and II, p.5).

3 Authors are now citing from many more different sources than in 1990, as measured by unique sources per article. The extent to which this is due to easier access to online materials (free and commercial) or simply a function of the proliferation in the number of sources over that period is unclear.

4 More sources are being cited than ever before, and the shape of the distribution is changing (Fig.1, p.5). The `long tail' is gradually becoming leaner as well as longer.

5 An analysis of UK papers by publication year (Annex 2, pp.13-24) shows that this effect is particularly marked in the biological sciences, chemistry, economics and econometrics, and physics. No such effect can be shown for earth and environmental sciences or history, where the overall shape of the citation distribution remains relatively stable over the period 1990-2007.

6 Another key finding of this report is that UK researchers are citing *older* papers than previously: in all disciplines, except history which proved to be a difficult case to collect meaningful data, the average age of citations has increased over the period 1990-2007 (Table IV, p.6). As well as a general increase in the average age of references, the proportion of materials cited within a five-year time window has decreased (Table VI, p. 7).

7 One of the original intentions of this paper was to present publication data on an annual basis to see whether any significant `bumps' in the graphs might relate to major events in the information landscape, such as the widespread deployment of browser software or Big

Deals. There are signs in five of the UK disciplines (but not physics) that the period around 1993-1994 co-incided with a sharp growth in the number of references and sources cited, perhaps as a direct result of the availability of the public web (Figures 1-6, Annex 2). Beyond this, growth in citations appears reasonably linear. In the biological sciences, however, the number of references and sources cited appear to plateau around 1998 but to be moving into another rapid growth phase from 2006, possibly an RAE-related effect.

8 This growth, in references and sources cited, persists when account is taken of the number of articles published. This may be a sign that referencing behaviour has changed: it cannot simply be explained by `keeping up with the literature' (Figures 8-13).

Research context

The proposition

The RIN Project Board suggested that CIBER should look at referencing behaviour (`citations out') to test the proposition that the arrival of digital platforms and the choice and ease of access that they offer, is likely to have impacted upon that behaviour over the past two decades. Intuitively, we should expect to see researchers citing from a wider range of journal sources than in earlier years, before desktop discovery and access. This idea is explored in this short discussion paper. Data on referencing behaviour was collected for the six subject areas being considered in the RIN `Value' study using an online method. Three key reference points in time were considered:

- 1990 (pre-web, pre-digital library in any meaningful sense)
- 1995 (early digital library)
- 2007 (mature digital library, post Big Deal)

Data were collected for all ISI authors (`worldwide') and for papers by UK authors only to help elucidate trends and patterns. In the case of UK papers, the data were compiled annually for the period 1990-2007.

Research method

Thomson Scientific data were searched online in DialogClassic to identify sets of articles for each year and RIN subject area, defined by the nearest ISI subject category, e.g.

S SC=BIOLOGY/1990 AND DT=ARTICLE

Dialog RANK commands were then used to analyse those articles in terms of the works they had cited (*rank cw*), the number of references (*rank nr*) fields in those articles, and the age profile of those references (*rank cy*).

Definitions

The terms used in the tables and graphics in this paper are defined below.

articles – The number of articles published in that discipline. All other document types (e.g. letters, book reviews, notes, etc.) are excluded.
references – The total number of references (`citations out') contained in those articles.
sources – The total number of unique sources represented in those lists of references. A `unique source' is a journal title, a monograph, a report, etc. So while there may be 350 references to different papers in the *Journal of Combustible Ideas,* for our purposes it represents just a single source.
references/article and **sources/article** – Simple ratios derived from the above.
sources/1,000 references – Another simple ratio, this one aids comparison between disciplines by normalizing for the number of references: it is best thought of as an indicator of the `breadth of citation' in each discipline.

Findings

As anticipated, the results reveal a great deal of subject variation (Tables I and II).

Table I: Basic indicators, worldwide papers by discipline, 2007.

	Articles	Sources	Sources per article	Sources per 1,000 references
Biological sciences	78,373	263,487	3.36	83.67
Chemistry	113,892	280,611	2.46	80.64
Earth and environmental sciences	33,785	258,782	7.66	219.61
Economics and econometrics	10,137	91,526	9.03	291.73
History	3,927	140,953	23.95	667.39
Physics	108,606	278,884	2.57	101.50

Table II: Basic indicators, UK papers by discipline, 2007.

	Articles	Sources	Sources per article	Sources per 1,000 references
Biological sciences	7,031	26,737	3.80	91.50
Chemistry	5,700	17,926	3.14	94.75
Earth and environmental sciences	2,943	32,248	10.96	277.46
Economics and econometrics	1,474	20,379	13.83	395.24
History	495	16,843	34.03	733.39
Physics	6,846	22,705	3.32	117.47

It is evident that historians draw on a very much wider range of sources (primary and secondary) than those working in the social or natural sciences, as indicated by the average number of sources referenced per journal article (column 4). The final column highlights the differences on another comparative measure, this time number of sources per 1,000 references. UK researchers score significantly more highly on this measure than the international community as a whole, indicating that they draw on a wider range of sources, less narrowly focused.

Figure 1: Cumulative references and sources: UK physics, 1990-2007

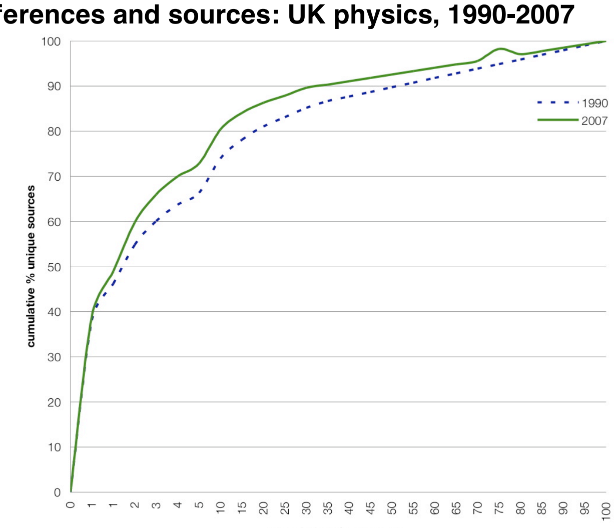


Figure 1 illustrates this shift in researcher behaviour by plotting cumulated references and sources for 1990 and 2007. Physics references in 2007 are characterized by having a thinner `long tail' than in 1990.

Table III provides evidence of considerable literature growth, in terms of total outputs, in all six disciplines. With the exception of history, there has also been a significant growth in the average number of references per article (increases in the range 33% for physics to 50% for earth and environmental sciences). So, we can conclude that researchers are citing more material than previously. They are also casting their net wider and citing a wider variety of unique sources (increases in the range 14% for history to 75% for earth and environmental sciences).

Table III: Literature growth against 1990 index, worldwide, by discipline.

		Articles	*References*	*Sources*	*Sources per 1,000 references*
Biological sciences	*by 1995*	47	51	74	1
	by 2007	106	179	192	5
Chemistry	*by 1995*	36	49	57	6
	by 2007	152	261	237	-7
Earth and environmental sciences	*by 1995*	38	51	49	-2
	by 2007	140	261	320	16
Economics and econometrics	*by 1995*	15	32	23	-7
	by 2007	91	180	128	-19
History	*by 1995*	9	6	4	2
	by 2007	-10	3	-6	10
Physics	*by 1995*	24	35	38	2
	by 2007	94	163	165	1

Researchers are making use of older references as well as drawing more widely across many more titles. Table IV shows that the average age of references has increased significantly since 1990. History has been excluded from this analysis for two reasons: the baseline of 1990 papers was low and, more importantly, this kind of material is very sensitive to changes in ISI indexing policy. The decision to index the *Journal of Cold War Studies* will obviously influence the distribution of history references in a different direction from *English Civil War Studies.*

Table IV: Average age of references, UK papers, no citation window

Age in years (mean)

	1990	*1995*	*2007*
Biological sciences	10.7	12.1	13.7
Chemistry	14.0	14.0	14.6
Earth and environmental sciences	13.4	14.6	16.6
Economics and econometrics	8.6	11.2	17.3
Physics	12.5	12.6	14.9

Table V uses a measure called the Herfindahl index (H_i)[1] to show how the age distribution of references has changed over time in each discipline. The index is often used in industrial studies to measure market concentrations in various sectors, and it varies between theoretical extremes of 0 (a free market with very many similarly-sized small suppliers) and 10,000 (a monopoly). In literature terms, if the references in a subject were very highly concentrated in one year, perhaps the year prior to publication, the value of H_i would be very large. If, as can be seen below, the references are spread out by year without too much bunching in particular periods, then the value of H_i is relatively low. The conclusion to be drawn from this and from Table IV is researchers are citing older materials and the distinction between current literature and the archive is gradually being etched away. This finding is consistent with CIBER deep log analysis and interview work: current awareness is no longer a mainstream academic pre-occupation: researchers pull information off the internet on a `need to know' basis.

Table V: Age concentration of references, UK papers, no citation window

Herfindahl index

	1990	*1995*	*2007*
Biological sciences	281	214	194
Chemistry	201	194	179
Earth and environmental sciences	271	181	160
Economics and econometrics	392	282	151
Physics	204	197	167

1=parity, 10,000=monopoly

This trend is reinforced in Table VI which shows that recent materials, those references published within a five-year window of the source article, make up a declining proportion of citations out.

Table VI: Age of references, 5-year citation window

Percentage of references within five years of source publication

	1990	*1995*	*2007*
Biological sciences	35.3	34.1	28.7
Chemistry	29.2	30.0	28.2
Earth and environmental sciences	29.9	28.6	24.3
Economics and econometrics	51.5	36.6	22.9
Physics	35.6	34.9	30.3

The picture that emerges from this report is that referencing behaviour has indeed changed over the past two decades. Over that period, the literature itself has grown very substantially (Mabe 2003) and there is much more choice on offer in most disciplines than ever before: and that is even if we simply consider `official' journals, let alone the explosion of content on the web. The findings here come as no surprise to us at CIBER in that they strongly reinforce what we already know about user behaviour. However, to move from these kinds of experimental data to simple explanations of what is going on is more difficult. If we take the flattening age profile of references as an example, there are several possible factors at play here. One is the tendency

[1] The Herfindhal index is the sum of the percentage market shares of all the participants. In a monopoly, its value is 10,000 (100*100). In a market with forty equally sized players, its value would be 40*(2.5*2.5)=250.

of many search engines to present output by relevance rather than reverse chronological order, another the increasing availability of backfiles, as well as changing attitudes to current awareness that we have documented in focus group discussions with senior and upcoming researchers. A recent JASIST paper (Barrett & Fink, 2008) also finds that citations are becoming older on average but suggests that the ageing of the researcher population offers a better fit with their findings than `internet-related' factors. An ageing professoriate still peddling the same old references! An earlier paper by Liu (2002), before the massive content explosion really got under way found that computer scientists were referring to earlier material even “under today's networked environment where new information is easily accessible”.

The fact that the number of references has grown so enormously over the period is a fact that is worthy of further investigation, especially the extent to which this growth is search-engine / ease-of-access driven. The graphics in Annex A are very difficult to interpret from a supply-side perspective – we can see a definite change in publications patterns co-inciding with the arrival of browser software and hypertext in the early to mid-1990s, after that, only conjecture as to the possible impacts of Big Deals, repositories and so on. Much more carefully controlled work would be needed to get anywhere identifying causes and effects here.

Perhaps the most intriguing finding here, and one that is complemented by a recent paper in Science (Evans, 2008) relates to how references are becoming more concentrated. The effect is of course masked by the growth of the literature, but both Evans and this CIBER paper find that researchers are making more intensive use of sources in the core and early tail of the literature. Evan's explanation that this narrowing of attention is a function of the electronic tools that researchers now rely on with such total dependence, seems to us totally credible. However, Evans' work has been inaccurately reported in the media and in the blogosphere to indicate this narrowing as an absolute truth rather than a relative shift in the distribution of references to sources.

All the findings in this report are consistent with the work of Carol Tenopir on the reading habits and preferences of researchers. She has found from self-reported surveys that researchers are reading and browsing more widely and that they are going further back in time.

References

Barnett, G.A. & Fink, E.L. (2008). Impact of the internet and scholar age distribution on academic citation age, *Journal of the American Society for Information Science and Technology* 59(4), pp. 526-534.

Evans, J.A. (2008). Electronic publication and the narrowing of science and scholarship, *Science* 321, pp. 395-399.

Liu, Z. (2003). Trends in transforming scholarly communication and their implications, *Information Processing & Management* 39(6), pp. 889-898.

Mabe, M.A. (2003). The growth and number of journals, *Serials* 16(2), pp. 191-197.

Annex 1: Worldwide data

Biological sciences

Table VII: Biological sciences *worldwide* (raw data)
(ISI SUBJECT CATEGORY=BIOLOGY

Year	Articles	References	Sources	Refs /article	Sources / article	Sources / 1,000 refs
1990	38,057	1,127,486	90,261	29.63	2.37	**80.06**
1995	56,012	1,929,483	156,748	34.45	2.80	**81.24**
2007	78,373	3,149,215	263,487	40.18	3.36	**83.67**

Table VIII: Biological sciences *worldwide* (Index=1990)

Year	Articles	References	Sources	Refs /article	Sources / article	Sources / 1,000 refs
1990	100	100	100	100	100	**100**
1995	147	151	174	116	118	**101**
2007	206	279	292	136	142	**105**

Chemistry

Table IX: Chemistry *worldwide* (raw data)
(ISI SUBJECT CATEGORY=CHEMISTRY)

Year	Articles	References	Sources	Refs /article	Sources / article	Sources / 1,000 refs
1990	45,185	962,711	83,205	21.31	1.84	**86.43**
1995	61,249	1,433,048	130,973	23.40	2.14	**91.39**
2007	113,892	3,479,820	280,611	30.55	2.46	**80.64**

Table X: Chemistry *worldwide* (Index=1990)

Year	Articles	References	Sources	Refs /article	Sources / article	Sources / 1,000 refs
1990	100	100	100	100	100	**100**
1995	136	149	157	110	116	**106**
2007	252	361	337	143	134	**93**

Earth and environmental sciences

Table XI: Earth and environmental sciences *worldwide* (raw data)
(ISI SUBJECT CATEGORY= GEOSCIENCES OR ENVIRONMENTAL SCIENCES)

Year	Articles	References	Sources	Refs /article	Sources / article	Sources / 1,000 refs
1990	14,071	326,042	61,672	23.17	4.38	**189.15**
1995	19,412	492,083	91,587	25.35	4.72	**186.12**
2007	33,785	1,178,376	258,782	34.87	7.66	**219.61**

Table XII: Earth and environmental sciences *worldwide* (Index=1990)

Year	Articles	References	Sources	Refs /article	Sources / article	Sources / 1,000 refs
1990	100	100	100	100	100	**100**
1995	138	151	149	109	108	**98**
2007	240	361	420	150	175	**116**

Economics and econometrics

Table XIII: Economics and econometrics *worldwide* (raw data)
(ISI SUBJECT CATEGORY=ECONOMICS)

Year	Articles	References	Sources	Refs /article	Sources / article	Sources / 1,000 refs
1990	5,309	112,125	40,193	21.12	7.57	**358.47**
1995	6,107	148,419	49,637	24.30	8.13	**334.44**
2007	10,137	313,733	91,526	30.95	9.03	**291.73**

Table XIV: Economics and econometrics *worldwide* (Index=1990)

Year	Articles	References	Sources	Refs /article	Sources / article	Sources / 1,000 refs
1990	100	100	100	100	100	**100**
1995	115	132	123	115	107	**93**
2007	191	280	228	147	119	**81**

History

Table XV: History *worldwide* (raw data)
(ISI SUBJECT CATEGORY=HISTORY)

Year	Articles	References	Sources	Refs /article	Sources / article	Sources / 1,000 refs
1990	4,348	149,814	91,171	34.46	20.97	**608.56**
1995	4,746	155,522	96,304	32.77	20.29	**619.23**
2007	3,927	140,953	94,071	35.89	23.95	**667.39**

Table XVI: History *worldwide* (Index=1990)

Year	Articles	References	Sources	Refs /article	Sources / article	Sources / 1,000 refs
1990	100	100	100	100	100	**100**
1995	109	106	104	95	97	**102**
2007	90	103	94	104	114	**110**

Physics

Table XVII: Physics *worldwide* (raw data)
(ISI SUBJECT CATEGORY=PHYSICS)

Year	Articles	References	Sources	Refs /article	Sources / article	Sources / 1,000 refs
1990	56,082	1,065,120	106,164	18.99	1.89	**99.67**
1995	69,643	1,436,124	146,381	20.62	2.10	**101.93**
2007	108,606	2,747,633	278,884	25.30	2.57	**101.50**

Table XVIII: Physics *worldwide* (Index=1990)

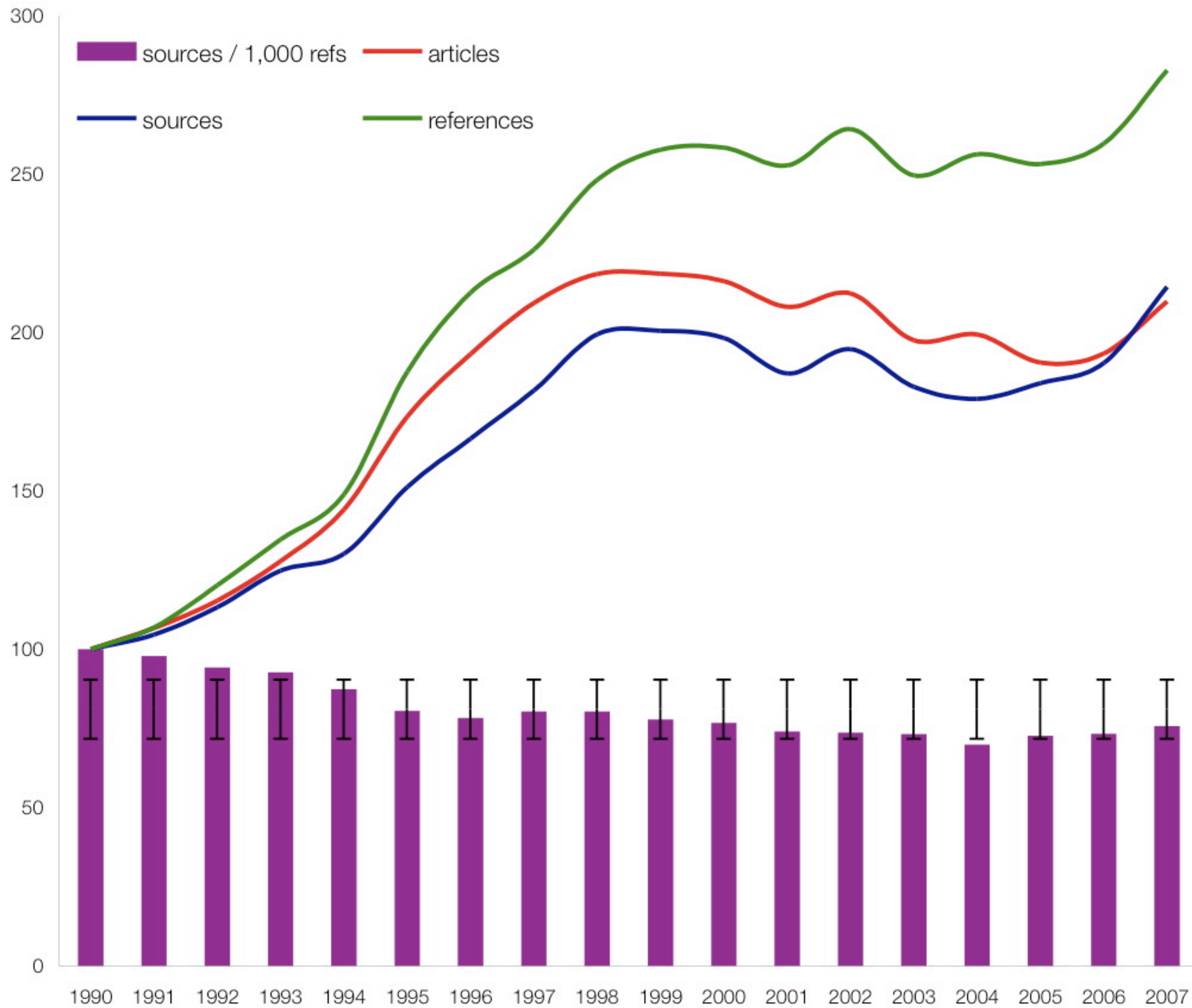
Year	Articles	References	Sources	Refs /article	Sources / article	Sources / 1,000 refs
1990	100	100	100	100	100	**100**
1995	124	135	138	109	111	**102**
2007	194	263	265	133	136	**101**

Annex 2: UK data, absolute growth

Table XIX: Biological sciences, *UK* (raw data and 1990 indices)

	Articles [A]	*Sources [S]*	*Refs [R]*	*[S]/[A]*	*[S]/[kR]*
1990	3,351	12,473	103,329	3.72	120.71
1991	3,577	13,047	110,441	3.65	118.14
1992	3,865	14,134	124,266	3.66	113.74
1993	4,284	15,571	139,120	3.63	111.92
1994	4,830	16,237	153,877	3.36	105.52
1995	5,814	18,869	193,984	3.25	97.27
1996	6,475	20,765	219,630	3.21	94.55
1997	7,014	22,670	233,768	3.23	96.98
1998	7,322	24,878	256,468	3.40	97.00
1999	7,324	25,011	266,272	3.41	93.93
2000	7,245	24,726	266,926	3.41	92.63
2001	6,974	23,334	261,133	3.35	89.36
2002	7,114	24,288	273,016	3.41	88.96
2003	6,618	22,806	257,845	3.45	88.45
2004	6,679	22,335	264,806	3.34	84.34
2005	6,383	22,955	261,580	3.60	87.76
2006	6,480	23,752	268,336	3.67	88.52
2007	7,031	26,737	292,196	3.80	91.50
Total	**108,380**	**374,588**	**3,946,993**		
Index=1990	*Articles [A]*	*Sources [S]*	*Refs [R]*	*[S]/[A]*	*[S]/[kR]*
1990	100.0	100.0	100.0	100.0	100.0
1991	106.7	104.6	106.9	98.0	97.9
1992	115.3	113.3	120.3	98.2	94.2
1993	127.8	124.8	134.6	97.6	92.7
1994	144.1	130.2	148.9	90.3	87.4
1995	173.5	151.3	187.7	87.2	80.6
1996	193.2	166.5	212.6	86.2	78.3
1997	209.3	181.8	226.2	86.8	80.3
1998	218.5	199.5	248.2	91.3	80.4
1999	218.6	200.5	257.7	91.7	77.8
2000	216.2	198.2	258.3	91.7	76.7
2001	208.1	187.1	252.7	89.9	74.0
2002	212.3	194.7	264.2	91.7	73.7
2003	197.5	182.8	249.5	92.6	73.3
2004	199.3	179.1	256.3	89.8	69.9
2005	190.5	184.0	253.2	96.6	72.7
2006	193.4	190.4	259.7	98.5	73.3
2007	209.8	214.4	282.8	102.2	75.8

Figure 2: Biological sciences, *UK*



In this and the subsequent graphics, the lines represent the indexed (1990) growth in articles, references and cited journals. The bars represent the number of unique sources per 1,000 references. They are shown with error bars indicating one standard deviation from the mean.

Table XX: Chemistry, *UK* (raw data and 1990 indices)

Year	*Articles [A]*	*Sources [S]*	*Refs [R]*	*[S]/[A]*	*[S]/[kR]*
1990	3,123	8,202	68,845	2.63	119.14
1991	3,418	9,314	75,137	2.72	123.96
1992	3,964	10,719	90,406	2.70	118.57
1993	4,102	11,399	91,663	2.78	124.36
1994	4,272	11,854	97,164	2.77	122.00
1995	4,421	12,663	108,456	2.86	116.76
1996	5,088	13,808	123,588	2.71	111.73
1997	5,239	15,038	132,115	2.87	113.83
1998	5,287	14,528	134,441	2.75	108.06
1999	5,344	15,684	135,812	2.93	115.48
2000	5,267	15,192	140,240	2.88	108.33
2001	5,116	15,204	138,756	2.97	109.57
2002	5,226	15,537	145,949	2.97	106.45
2003	5,132	15,301	148,281	2.98	103.19
2004	5,342	16,139	157,175	3.02	102.68
2005	5,302	16,727	168,124	3.15	99.49
2006	5,640	16,929	181,916	3.00	93.06
2007	5,700	17,926	189,183	3.14	94.75
Total	**86,983**	**252,164**	**2,327,251**		
Index=1990	*Articles [A]*	*Sources [S]*	*Refs [R]*	*[S]/[A]*	*[S]/[kR]*
1990	100.0	100.0	100.0	100.0	100.0
1991	109.4	113.6	109.1	103.8	104.0
1992	126.9	130.7	131.3	103.0	99.5
1993	131.3	139.0	133.1	105.8	104.4
1994	136.8	144.5	141.1	105.7	102.4
1995	141.6	154.4	157.5	109.1	98.0
1996	162.9	168.3	179.5	103.3	93.8
1997	167.8	183.3	191.9	109.3	95.5
1998	169.3	177.1	195.3	104.6	90.7
1999	171.1	191.2	197.3	111.7	96.9
2000	168.7	185.2	203.7	109.8	90.9
2001	163.8	185.4	201.5	113.2	92.0
2002	167.3	189.4	212.0	113.2	89.4
2003	164.3	186.6	215.4	113.5	86.6
2004	171.1	196.8	228.3	115.0	86.2
2005	169.8	203.9	244.2	120.1	83.5
2006	180.6	206.4	264.2	114.3	78.1
2007	182.5	218.6	274.8	119.7	79.5

Figure 3: Chemistry, *UK*

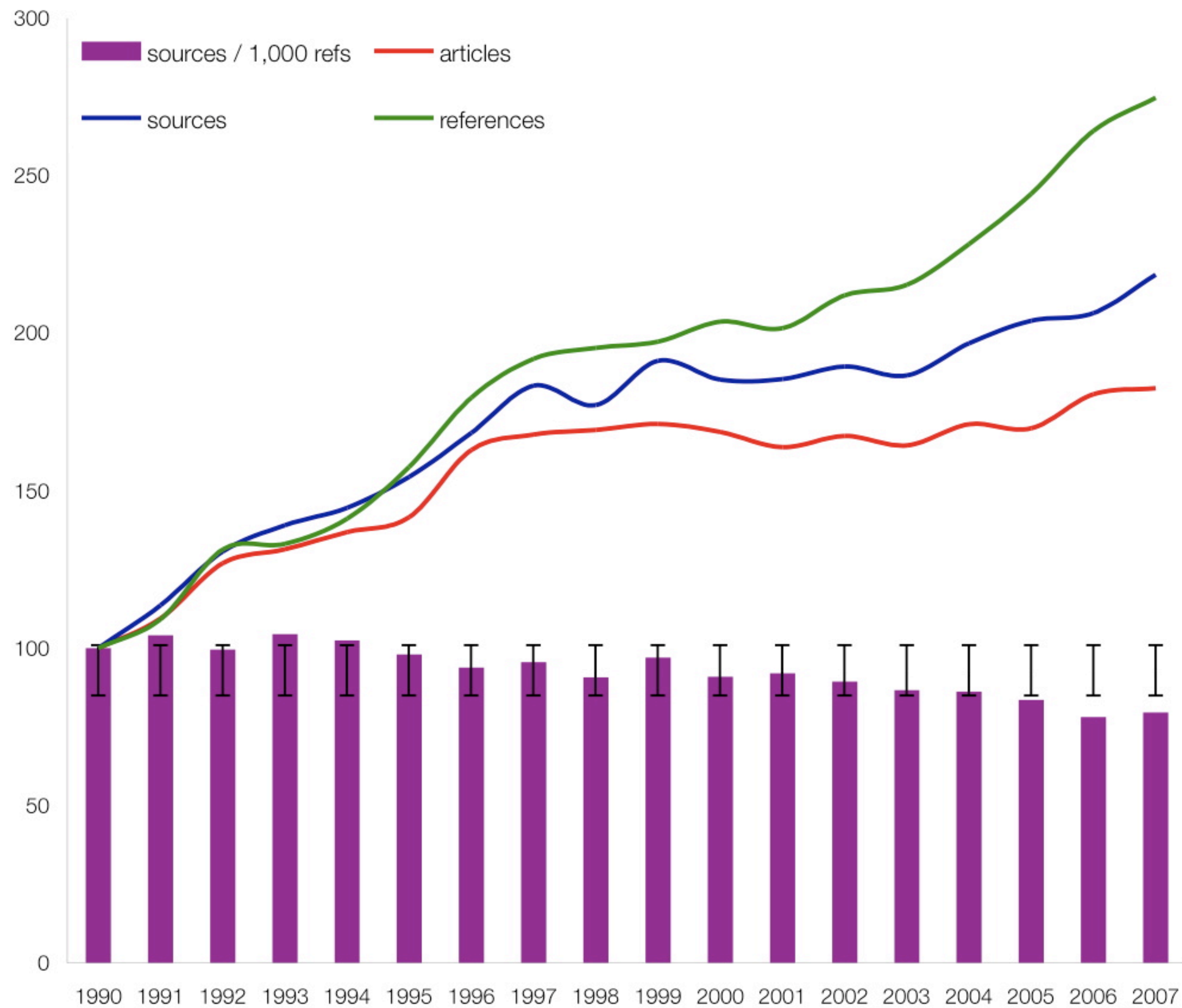


Table XXI: Earth and environmental sciences, *UK* (raw data and 1990 indices)

	Articles [A]	*Sources [S]*	*Refs [R]*	*[S]/[A]*	*[S]/[kR]*
1990	1,109	8,506	29,215	7.67	291.15
1991	1,111	8,754	29,675	7.88	295.00
1992	1,352	10,262	35,357	7.59	290.24
1993	1,567	11,544	39,798	7.37	290.06
1994	1,573	11,412	39,461	7.25	289.20
1995	1,982	14,785	53,508	7.46	276.31
1996	1,692	16,395	49,205	9.69	333.20
1997	1,928	17,241	55,044	8.94	313.22
1998	2,180	19,829	67,970	9.10	291.73
1999	2,251	21,478	72,329	9.54	296.95
2000	2,363	22,725	78,652	9.62	288.93
2001	2,433	22,808	81,800	9.37	278.83
2002	2,394	22,478	83,503	9.39	269.19
2003	2,602	24,623	88,282	9.46	278.91
2004	2,572	25,368	92,060	9.86	275.56
2005	2,657	26,853	96,259	10.11	278.97
2006	2,830	29,413	107,604	10.39	273.34
2007	2,943	32,248	116,225	10.96	277.46
Total	**37,539**	**346,722**	**1,215,947**		
Index=1990	*Articles [A]*	*Sources [S]*	*Refs [R]*	*[S]/[A]*	*[S]/[kR]*
1990	100.0	100.0	100.0	100.0	100.0
1991	100.2	102.9	101.6	102.7	101.3
1992	121.9	120.6	121.0	99.0	99.7
1993	141.3	135.7	136.2	96.0	99.6
1994	141.8	134.2	135.1	94.6	99.3
1995	178.7	173.8	183.2	97.3	94.9
1996	152.6	192.7	168.4	126.3	114.4
1997	173.9	202.7	188.4	116.6	107.6
1998	196.6	233.1	232.7	118.6	100.2
1999	203.0	252.5	247.6	124.4	102.0
2000	213.1	267.2	269.2	125.4	99.2
2001	219.4	268.1	280.0	122.2	95.8
2002	215.9	264.3	285.8	122.4	92.5
2003	234.6	289.5	302.2	123.4	95.8
2004	231.9	298.2	315.1	128.6	94.6
2005	239.6	315.7	329.5	131.8	95.8
2006	255.2	345.8	368.3	135.5	93.9
2007	265.4	379.1	397.8	142.9	95.3

Figure 4: Earth and environmental sciences, *UK*

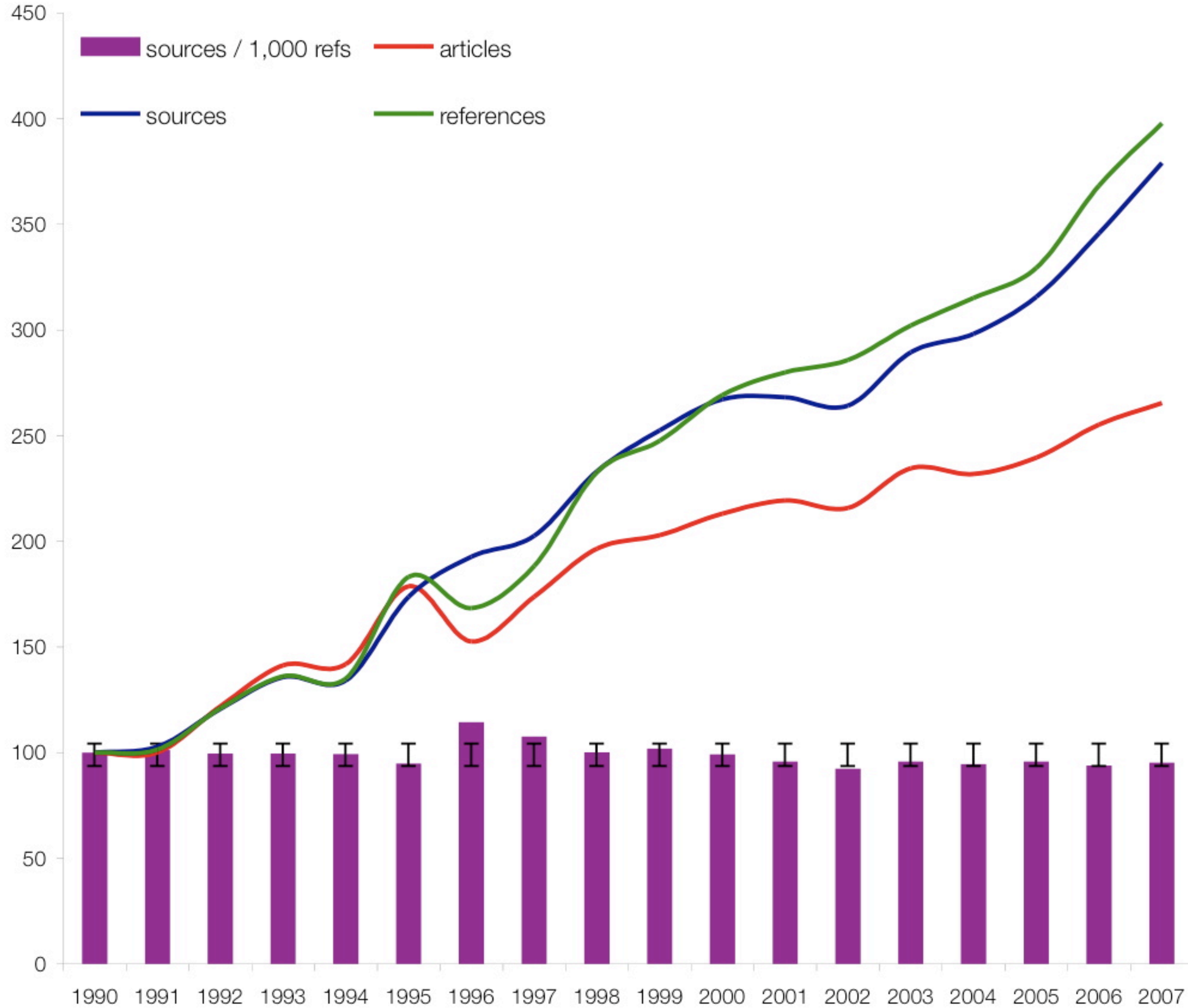


Table XXII: Economics and econometrics, *UK* (raw data and 1990 indices)

	Articles [A]	Sources [S]	Refs [R]	[S]/[A]	[S]/[kR]
1990	430	5,398	10,450	12.55	516.56
1991	547	7,099	14,239	12.98	498.56
1992	562	6,906	14,308	12.29	482.67
1993	567	7,215	14,128	12.72	510.69
1994	670	8,687	17,724	12.97	490.13
1995	746	9,005	19,610	12.07	459.20
1996	879	10,686	23,737	12.16	450.18
1997	858	10,424	23,095	12.15	451.35
1998	928	12,346	26,496	13.30	465.96
1999	957	12,428	27,087	12.99	458.82
2000	1,059	14,234	31,607	13.44	450.34
2001	1,006	13,443	30,393	13.36	442.31
2002	1,025	13,735	31,958	13.40	429.78
2003	1,108	14,444	34,205	13.04	422.28
2004	1,142	15,039	36,552	13.17	411.44
2005	1,174	16,479	39,683	14.04	415.27
2006	1,237	17,317	42,211	14.00	410.25
2007	1,474	20,379	51,561	13.83	395.24
Total	**16,369**	**215,264**	**489,044**		
Index=1990	*Articles [A]*	*Sources [S]*	*Refs [R]*	*[S]/[A]*	*[S]/[kR]*
1990	100.0	100.0	100.0	100.0	100.0
1991	127.2	131.5	136.3	103.4	96.5
1992	130.7	127.9	136.9	97.9	93.4
1993	131.9	133.7	135.2	101.4	98.9
1994	155.8	160.9	169.6	103.3	94.9
1995	173.5	166.8	187.7	96.2	88.9
1996	204.4	198.0	227.1	96.8	87.2
1997	199.5	193.1	221.0	96.8	87.4
1998	215.8	228.7	253.6	106.0	90.2
1999	222.6	230.2	259.2	103.4	88.8
2000	246.3	263.7	302.5	107.1	87.2
2001	234.0	249.0	290.8	106.4	85.6
2002	238.4	254.4	305.8	106.7	83.2
2003	257.7	267.6	327.3	103.8	81.7
2004	265.6	278.6	349.8	104.9	79.7
2005	273.0	305.3	379.7	111.8	80.4
2006	287.7	320.8	403.9	111.5	79.4
2007	342.8	377.5	493.4	110.1	76.5

Figure 5: Economics and econometrics, *UK*

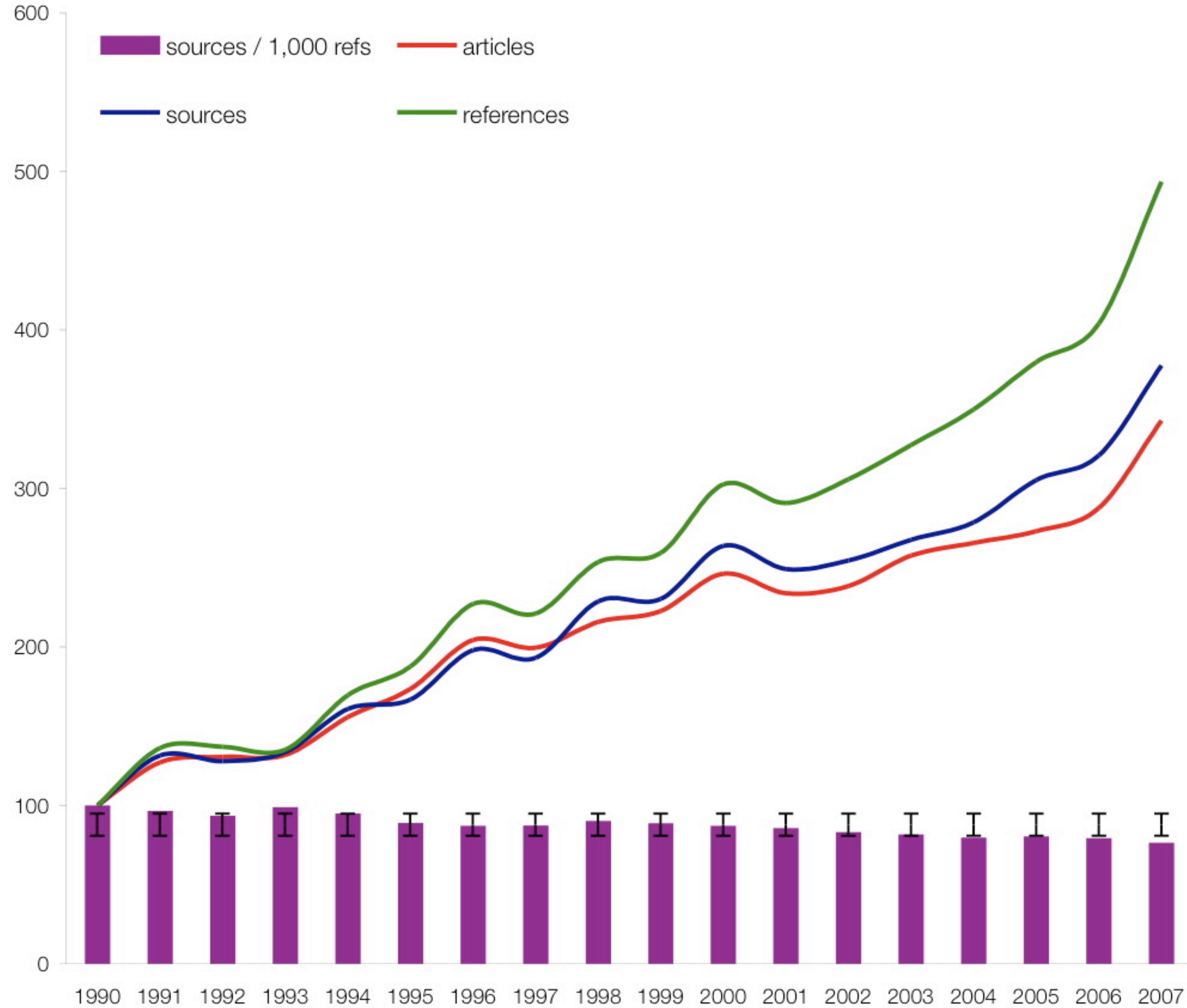


Table XXIII: History, *UK* (raw data and 1990 indices)

Year	Articles [A]	Sources [S]	Refs [R]	[S]/[A]	[S]/[kR]
1990	319	9,531	13,338	29.88	714.57
1991	325	9,488	12,913	29.19	734.76
1992	317	9,989	13,210	31.51	756.17
1993	345	9,684	13,487	28.07	718.02
1994	384	11,971	16,281	31.17	735.27
1995	410	12,408	17,214	30.26	720.81
1996	445	13,615	18,901	30.60	720.33
1997	451	11,815	15,565	26.20	759.07
1998	540	15,799	21,476	29.26	735.66
1999	526	14,503	18,988	27.57	763.80
2000	655	18,778	25,070	28.67	749.02
2001	554	15,768	20,661	28.46	763.18
2002	522	15,331	19,630	29.37	781.00
2003	536	16,316	21,871	30.44	746.01
2004	504	16,510	21,858	32.76	755.33
2005	505	18,223	24,925	36.09	731.11
2006	547	18,420	24,875	33.67	740.50
2007	495	16,843	22,966	34.03	733.39
Total	**8,380**	**254,992**	**343,229**		
Index=1990	*Articles [A]*	*Sources [S]*	*Refs [R]*	*[S]/[A]*	*[S]/[kR]*
1990	100.0	100.0	100.0	100.0	100.0
1991	101.9	99.5	96.8	97.7	102.8
1992	99.4	104.8	99.0	105.5	105.8
1993	108.2	101.6	101.1	93.9	100.5
1994	120.4	125.6	122.1	104.3	102.9
1995	128.5	130.2	129.1	101.3	100.9
1996	139.5	142.8	141.7	102.4	100.8
1997	141.4	124.0	116.7	87.7	106.2
1998	169.3	165.8	161.0	97.9	103.0
1999	164.9	152.2	142.4	92.3	106.9
2000	205.3	197.0	188.0	96.0	104.8
2001	173.7	165.4	154.9	95.3	106.8
2002	163.6	160.9	147.2	98.3	109.3
2003	168.0	171.2	164.0	101.9	104.4
2004	158.0	173.2	163.9	109.6	105.7
2005	158.3	191.2	186.9	120.8	102.3
2006	171.5	193.3	186.5	112.7	103.6
2007	155.2	176.7	172.2	113.9	102.6

Figure 6: History, *UK*

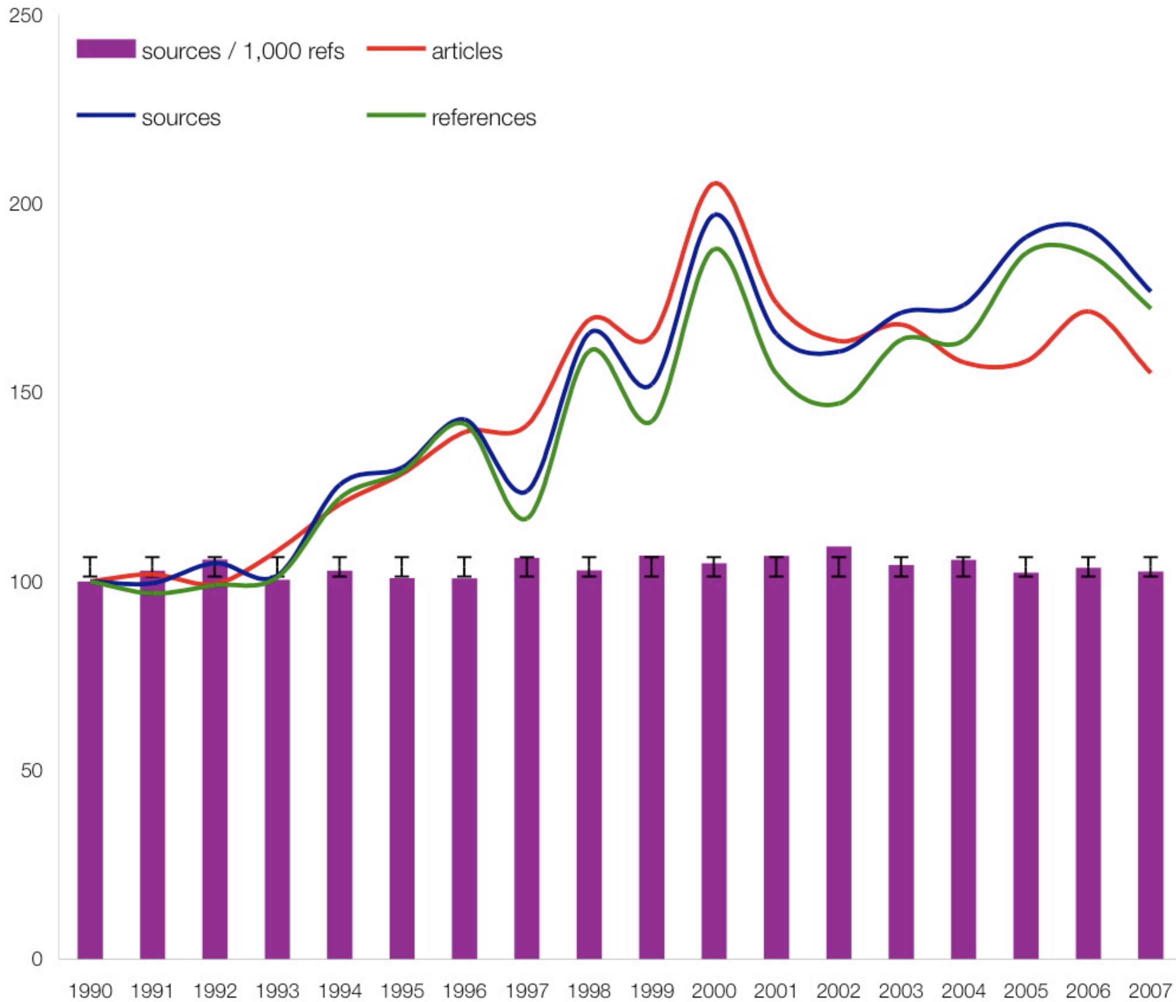
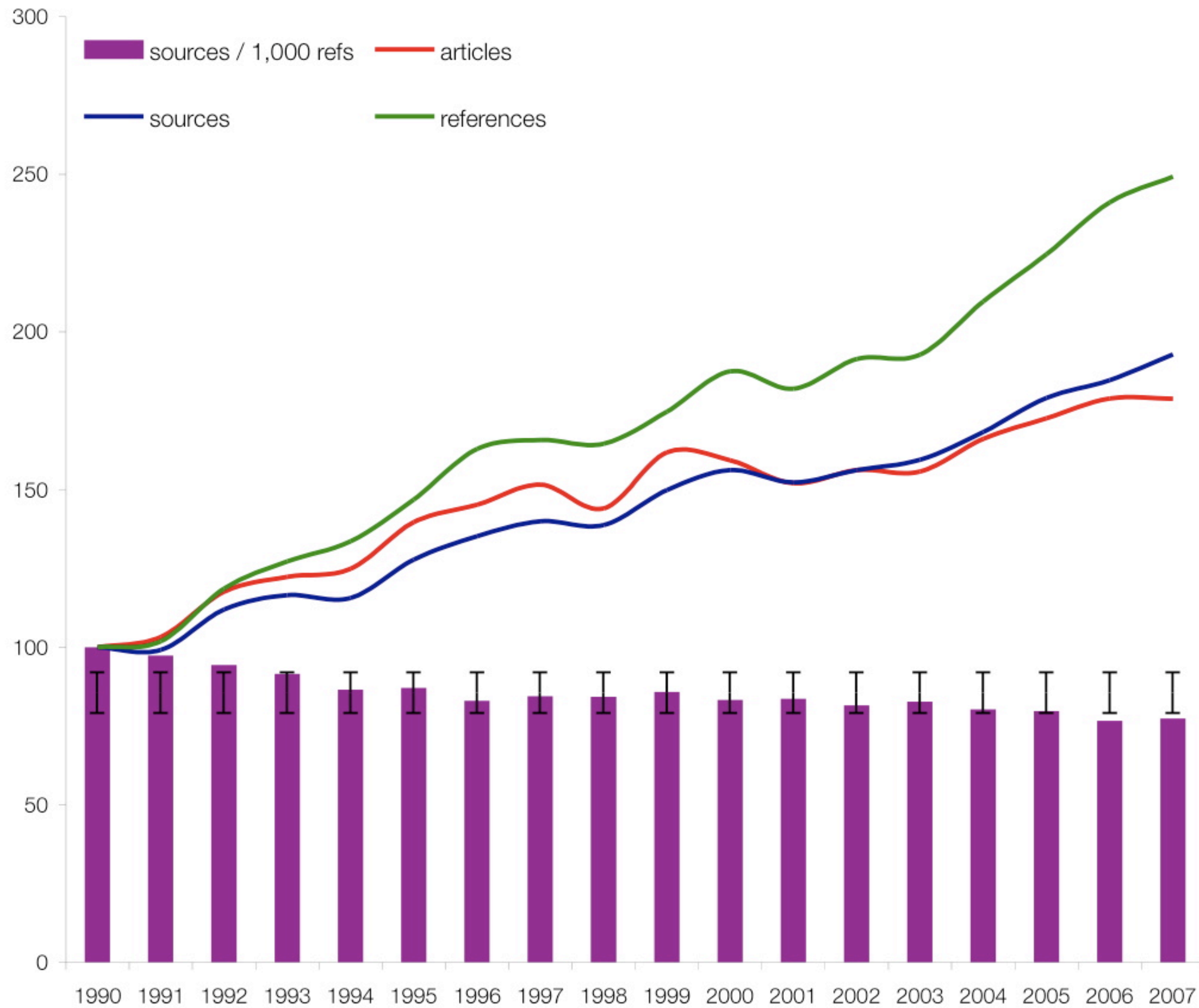


Table XXIV: Physics, *UK* (raw data and 1990 indices)

	Articles [A]	Sources [S]	Refs [R]	[S]/[A]	[S]/[kR]
1990	3,829	11,771	77,543	3.07	151.80
1991	3,952	11,672	79,029	2.95	147.69
1992	4,503	13,174	91,973	2.93	143.24
1993	4,682	13,711	98,667	2.93	138.96
1994	4,781	13,609	103,562	2.85	131.41
1995	5,346	15,043	113,823	2.81	132.16
1996	5,558	15,911	126,293	2.86	125.98
1997	5,802	16,471	128,521	2.84	128.16
1998	5,514	16,331	127,609	2.96	127.98
1999	6,194	17,637	135,441	2.85	130.22
2000	6,099	18,385	145,416	3.01	126.43
2001	5,820	17,920	141,122	3.08	126.98
2002	5,981	18,380	148,441	3.07	123.82
2003	5,962	18,767	149,480	3.15	125.55
2004	6,360	19,805	162,569	3.11	121.83
2005	6,610	21,079	174,214	3.19	120.99
2006	6,849	21,741	186,909	3.17	116.32
2007	6,846	22,705	193,288	3.32	117.47
Total	**100,688**	**304,112**	**2,383,900**		
Index=1990	*Articles [A]*	*Sources [S]*	*Refs [R]*	*[S]/[A]*	*[S]/[kR]*
1990	100.0	100.0	100.0	100.0	100.0
1991	103.2	99.2	101.9	96.1	97.3
1992	117.6	111.9	118.6	95.2	94.4
1993	122.3	116.5	127.2	95.3	91.5
1994	124.9	115.6	133.6	92.6	86.6
1995	139.6	127.8	146.8	91.5	87.1
1996	145.2	135.2	162.9	93.1	83.0
1997	151.5	139.9	165.7	92.3	84.4
1998	144.0	138.7	164.6	96.3	84.3
1999	161.8	149.8	174.7	92.6	85.8
2000	159.3	156.2	187.5	98.1	83.3
2001	152.0	152.2	182.0	100.2	83.7
2002	156.2	156.1	191.4	100.0	81.6
2003	155.7	159.4	192.8	102.4	82.7
2004	166.1	168.3	209.7	101.3	80.3
2005	172.6	179.1	224.7	103.7	79.7
2006	178.9	184.7	241.0	103.3	76.6
2007	178.8	192.9	249.3	107.9	77.4

Figure 7: Physics, *UK*



Annex 3: UK data, relative growth

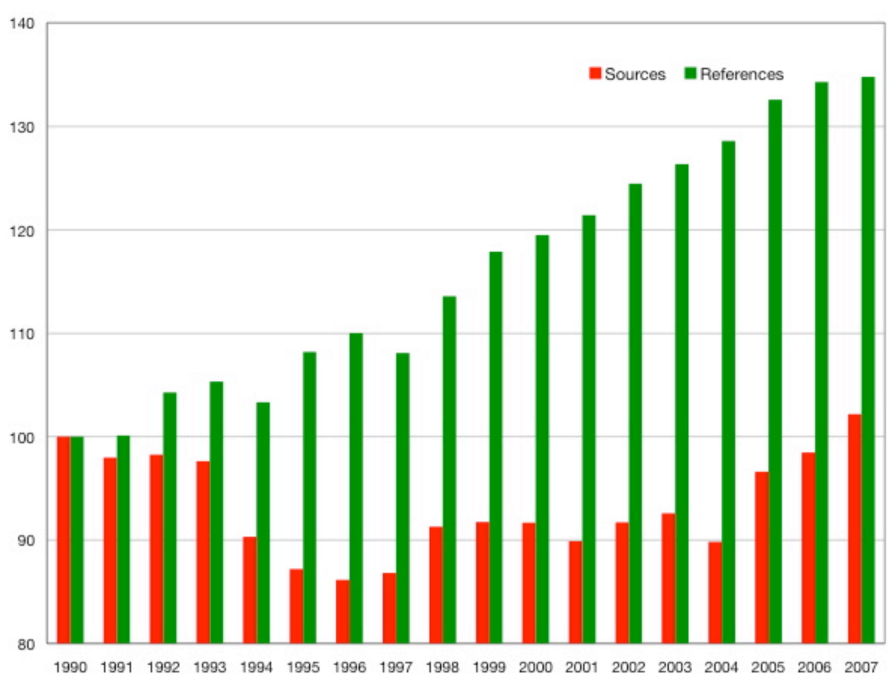
In this final section, the UK data in the previous tables are presented again on a different basis. The graphics show growth in the number of sources and the number of references over the period 1990-2007, both indexed to their starting value in 1990. However, this time, the data are normalized against the number of articles: this is held constant over the period so that the patterns can be seen more easily.

The overall pattern is that the number of references and sources has grown much faster than the number of articles in all disciplines. In the biological sciences, chemistry, economics and econometrics and physics, the growth in references cannot be attributed to a proliferation of new titles: references are growing much faster than new sources in these particular disciplines. In history and the earth and environmental sciences, reference growth and new sources are in closer harmony: but both have grown much faster than the number of articles.

It is not possible to explain these findings without much more detailed further work, but the fact that reference lists appear to be growing much faster than the supply of new titles and new articles may suggest some new research questions. One implication may be that search and discovery tools are shaping referencing behaviour in ways that we cannot fully explain at this moment in time.

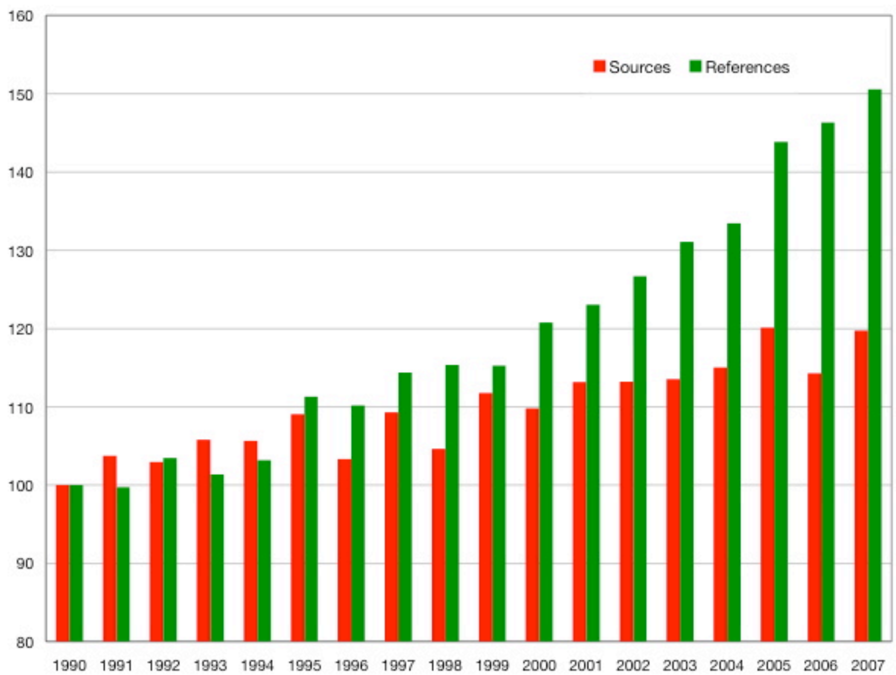
Biological sciences

Figure 8: Biological sciences, *UK relative growth*



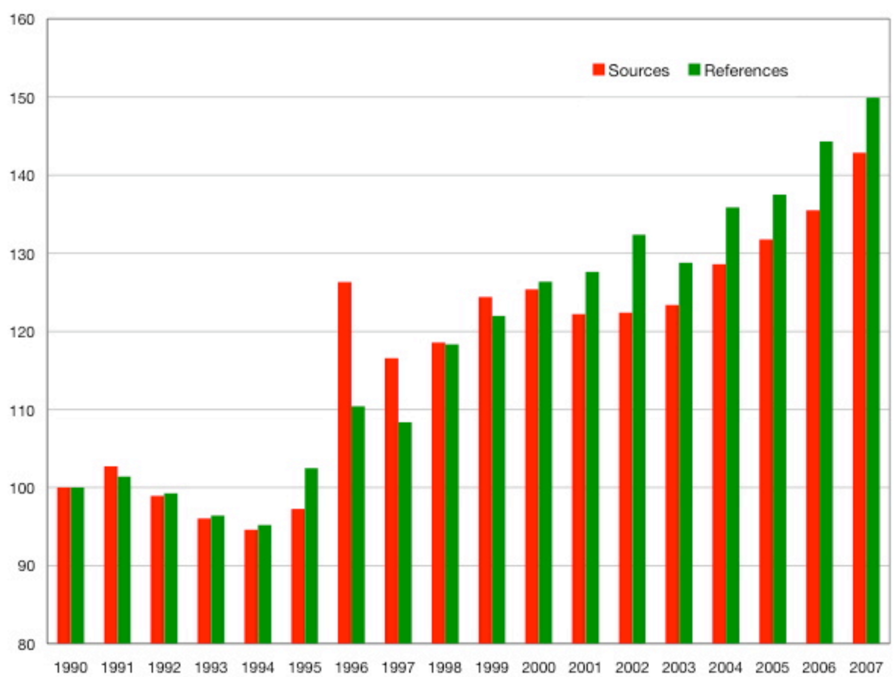
Chemistry

Figure 9: Chemistry, *UK relative growth*



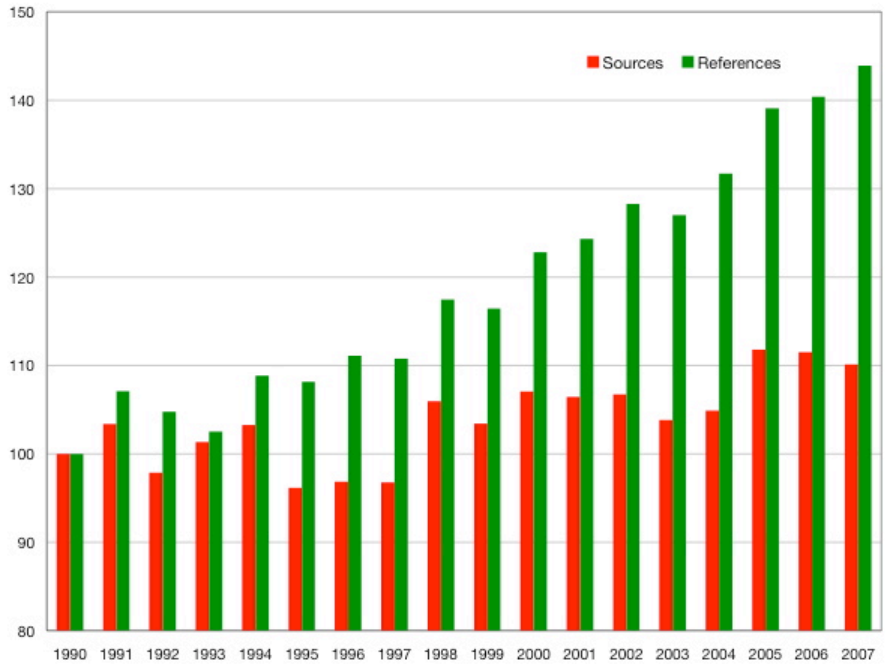
Earth and environmental sciences

Figure 10: Earth and environmental sciences, *UK relative growth*



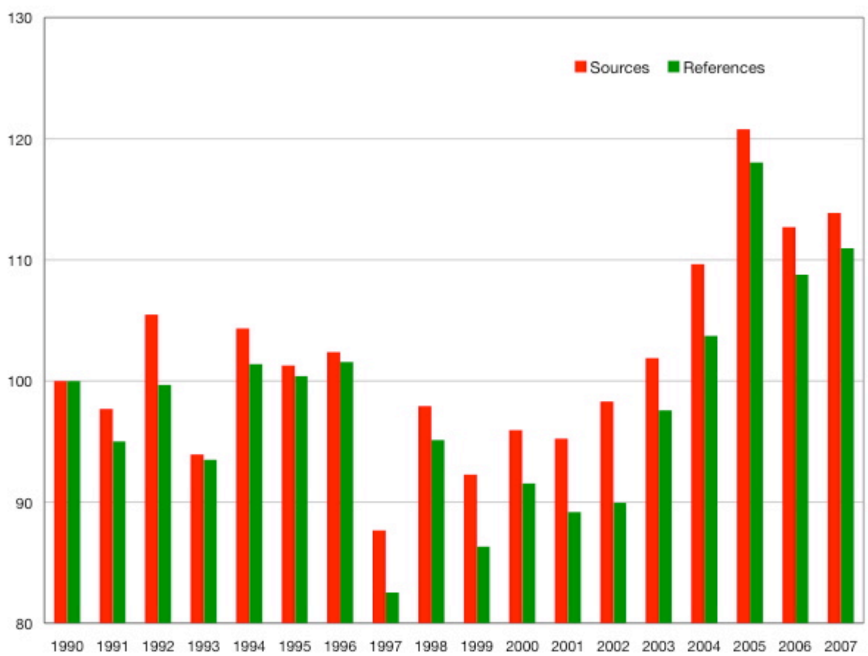
Economics and econometrics

Figure 11: Economics and econometrics, *UK relative growth*



History

Figure 12: History, *UK relative growth*



Physics

Figure 13: Physics, *UK relative growth*