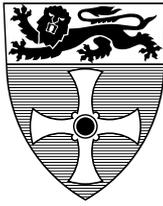


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An analysis of the dynamics of British academic science

P. Andras, N. D. J. Herald and B. G. Charlton.

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An analysis of the dynamics of British academic science

TECHNICAL REPORT

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Abstract

We analysed the ranking and market share dynamics of main British universities based on their research output production (publications and citations). The data that we analysed is dominated very much by research output in natural and medical sciences. We found that rankings based on citation counts are less variable than rankings based on publication counts. While ranking dynamics provides a coarse grained picture of the dynamics, the analysis of market share dynamics reveals more details of the mechanisms driving these dynamic processes. We suggest that most research output is produced in mature sciences producing normal science, and that this explains to a good extent the changes in market shares that we measured. We also suggest that having groups developing revolutionary science is critical for universities with large research output to keep their market share and for smaller universities to increase their market share rapidly.

1. Introduction

Rankings of British universities are compiled yearly by major newspapers (e.g. Times, 2003). These rankings consider teaching, research and other aspects of universities. The Research Assessment Exercise is run by the government and is aimed to assess and rank British universities and their research departments periodically, every 5-7 years (Hargreaves-Heap, 2002). However both types of above assessments and rankings are based to some extent on subjective or easy to manipulate criteria (e.g. peer opinion, formal evaluation of the teaching process, etc.). Here we describe a more objective evaluation of the dynamics of British academic science over the last 30 years using publication and citation data.

Publication and citation data has been collected and analysed systematically since the 1960s (e.g. De Solla Price, 1961, 1963; Bayers, 2005; Shelton and Holdridge 2004).

However until recently this data was collected through labour intensive processes involving the manual cataloguing of scientific journals and the papers that they publish. Recent advances in electronic accessibility of publication data and the electronic availability of publication databases (e.g. Web of Knowledge, PubMed, Scopus) make scientometric analysis easier in terms of availability of data, and also possibly more detailed and sophisticated thanks to the large volume of high quality data that is available. Of course such analysis can be also abused, and as it has been discussed very clearly by Van Raan (2005) any such analysis should be applied by considering the constraints and context that is implied by the nature of the analysed data (e.g. inconsistencies in names of institutions, wrong citations, domain specific publication practices, etc.)

In recent years several studies have been published on large scale evaluation of production of academic science. Bayers (2005) analysed the standing of German universities and research institutes for the period of 1998 – 2002 and also compared the production measures of major countries worldwide. Shelton and Holdridge (2004) compared the scientific performance of the US and the EU, and show that EU is catching up with US in many aspects of science output. Jacobson and Rickne (2004) analysed the size of Swedish academic science in terms of science metrics and compared science production in Sweden with other OECD countries, finding that Sweden is above average in output measures and below average in input measures. Recent analyses by Leydesdorff and Zhou (2005) and Zhou and Leydesdorff (2006) show that the Far East, and especially China is becoming a fast increasing player in the international economics of science production. Tuzi (2005) compared the science production of Italian regions and identified the strength of each region in terms of science domains. Altvater-Mackensen et al (2005) analysed the research specialisation of German regions in more detail in a similar manner. Similar analysis have been also applied in domain specific manner, for example to bioinformatics (Patra and Mishra, 2006), neuroscience (Glanzel et al, 2003), nanotechnology (Schummer, 2004), dermatology (Belinchon et al, 2004), economics (Sternberg and Litzenberg, 2005), and tropical medicine (Keiser and Utzinger, 2004).

Here we analyse the research output performance of 48 British universities. We selected those universities that existed as a university before 1975, and which did not change their name in the period between 1975 – 2005. Our analysis confirms that the number of papers and citations is much higher for all these universities in the domain

of natural and medical sciences than in the domain of social sciences, and the output produced in the latter domain is much larger than the output produced in the domain of arts and humanities. We show that ranking on the basis of citation counts is less variable than ranking on the basis of publication counts. We analyse the market share dynamics for these universities and find that the market share of most large universities are decreasing, while the few top universities maintain their market share, and a few improving universities manage to grow their market share. We discuss the relationship between Kuhnian normal and revolutionary science (Kuhn, 1996) and the data that we measured. We also discuss the dynamics of the research output markets and provide a brief explanation of the mechanisms of this dynamics.

The rest of the paper is structured as follows. First we describe the data that we used. Next we present our results. This is followed by the discussion. The paper is closed by our conclusions.

2. The data

We used the publication and citation data provided by the Web of Knowledge (WOK, 2006). The data was considered for the period between 1975 – 2005. The data is divided into three domains: Science (natural and medical sciences), Social Sciences and Arts and Humanities. We note that there is some overlap between the lists of journals considered for the three domains (for example some medical journals are also included in the Social Sciences domain).

The data was collected for 48 British universities (see the list of universities in the Appendix). We selected those universities which were universities before 1975 and which did not change their names between 1975 – 2005. Notable exclusions are Cardiff University (which was part of University of Wales) and the University of Manchester Institute of Science and Technology - UMIST (which joined the University of Manchester in 2004). For all universities we determined unique search strings, so that we collected only relevant data for them. In case of these universities we did not need unification of results (Van Raan, 2005), as their unique search string identified all their parts. We note that in the case of London colleges (Imperial, UCL, Kings, Royal Holloway) the considered universities were merged with medical schools and other research institutes and smaller colleges during the period 1975 – 2005. We did not include into our data output measurements of separate medical

schools (e.g. St George's Medical School) and research institutes (e.g. Cancer Research Institute).

For each considered university we counted the number of publications (all types of publications) for each year between 1975 – 2005 and for the combined three domains of the Web of Knowledge. We also counted for each university, and each year the number of citations that the corresponding publications received between the time of their publication and the time of data collection (February 2006). This means for example that for a paper published in 2001 we considered all citations received in the five years since its publication, while in the case of a paper published in 1991 we considered all citations that the paper received in the fifteen years since its publication. If a publication was written by multiple authors belonging to more than one considered university, the publication was counted for each university to which at least one of its authors belonged. For each year we calculated the total number of publications and total number of citations that these publications received since their publication until February 2006. Using the total publication and citation numbers we calculated the market share of each university in terms of publications and citations for each year and among the 48 considered universities (i.e. the total publication and citation market is considered to be the total output of these 48 universities). We also counted publications and citations for each considered university for five year periods (1975 – 1979 to 2000 – 2004) separately for each domain of the Web of Knowledge.

Possible sources of errors in our data include: mistyping of university names, missing citations, wrong attribution of citations, and double or multiple inclusion of publications or citations in the Web of Knowledge database. We believe that these potential errors do not distort significantly our data. We included in our counts all types of publications. Although in this way we include among publications for example book reviews and published non-peer reviewed correspondences, we adopted this approach for the sake of simplicity, and with the assumption that at the level of large numbers of publications and citations the distorting effects of publications that are not proper scientific publications is very minor and not significant.

3. Analysis

In this section we present our analysis results. First we report about the comparison of total output in the three domains of academic research (domains defined by the Web of Knowledge database – i.e. sciences, social sciences and arts and humanities).

Second we analyse the rank dynamics of British universities considering their rankings according to citations and publications across all domains of academic research. Third we analyse the market share dynamics of British universities in the ‘markets’ of publications and citations. Numerical data relevant for analysis conclusions is presented in the Appendix.

3.1. Comparison of domains of academic research

The data that we analysed confirms the common knowledge that science publications and citations outnumber massively the number of publications in the other two domains of academic research (i.e. social sciences and arts and humanities). The data also shows that there are several times more publications and citations in the domain of social sciences than in arts and humanities. We note that there are overlaps between domains, and in particular there are medical journals which are included in both sciences and social sciences, lifting up the number of publications and citations in the domain of social sciences.

For each five year period we calculated the ratio between the total counts of publications and citations calculated for the three domains of research (note that within the considered period the number of publications for five year periods in sciences tripled). Figure 1 shows the evolution of the ratios of publication counts for social sciences / sciences, arts and humanities / sciences, and arts and humanities / social sciences. Figure 2 shows the evolution corresponding ratios for citation counts. The data presented in Figures 1 and 2 shows that publications and citations in the domain of sciences dominate very much and increasingly over the considered period (1975 – 2004). The data also shows that arts and humanities publication counts increased compared to social sciences publication counts until the mid 1990s, and dropped since then. In terms of citation counts the increase of arts and humanities compared to social sciences happened until the early 1980s, and since then the ratio of these is dropping. Comparing the publication and citation data shows that the dominance of sciences is much more expressed in the case of citations, i.e. in case of publications sciences produce around 4 times more than social sciences and almost 10 times more than arts and humanities, while in case of citations the count for sciences is around 10 times more than the count for social sciences and more than 200 times more than the count for arts and humanities.

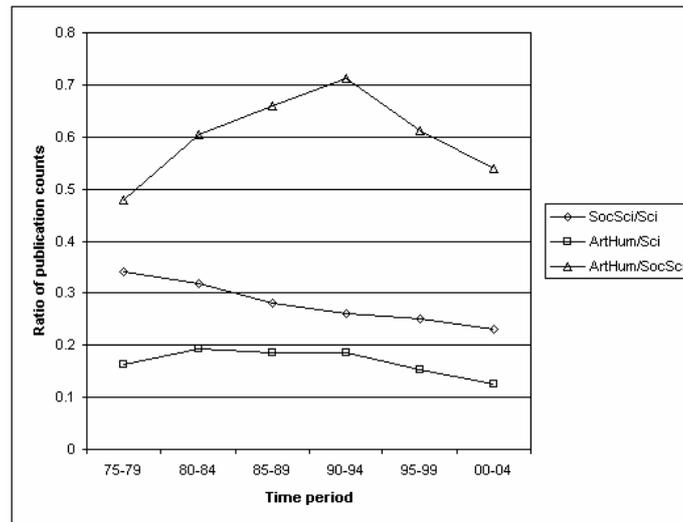


Figure 1. The evolution of ratios of total publication counts. The ratios shown are: social sciences / sciences (SocSci/Sci), arts and humanities / sciences (ArtHum/Sci) and arts and humanities / social sciences (ArtHum/SocSci).

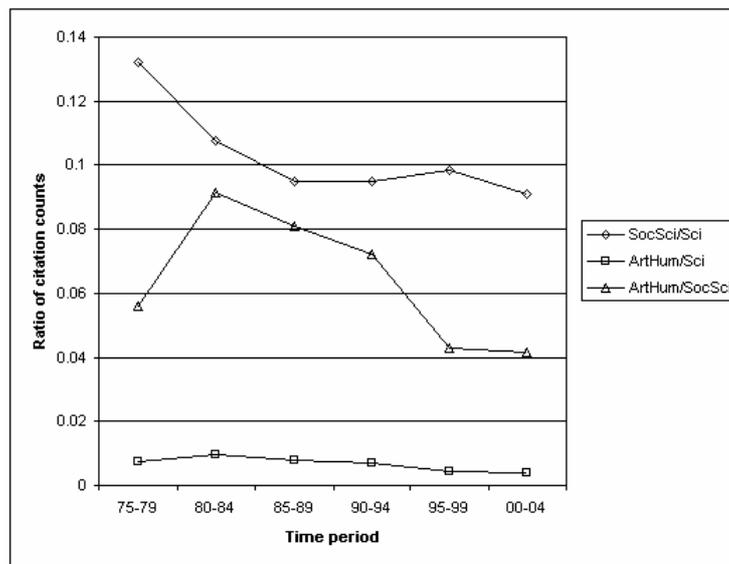


Figure 2. The evolution of ratios of total citation counts. The ratios shown are: social sciences / sciences (SocSci/Sci), arts and humanities / sciences (ArtHum/Sci) and arts and humanities / social sciences (ArtHum/SocSci).

The comparison of the domains of academic research in terms of publication and citation data available from the Web of Knowledge shows that the overall data is very much dominated by sciences. The dominance of sciences is much stronger in the case of citation counts than in the case of publication counts. This may be due to some extent to the range of journals that are considered for the Web of Knowledge database

(i.e. more science journals than arts and humanities journals are included). However, we believe that this phenomenon is due to a large extent to the publication practices in the three domains of academic research. The main implication of this finding is that the all our further analyses are driven primarily by data relevant for sciences, and to much less extent by data relevant for social sciences or arts and humanities.

3.2. Rank dynamics

We ranked the considered universities for each year according to their calculated publication and citation counts. We analysed the rank dynamics by comparing the ranks that universities achieved across all years. For each university we calculated their mean ranking over all years (1975 – 2005) and also the standard deviation of their rankings over these years.

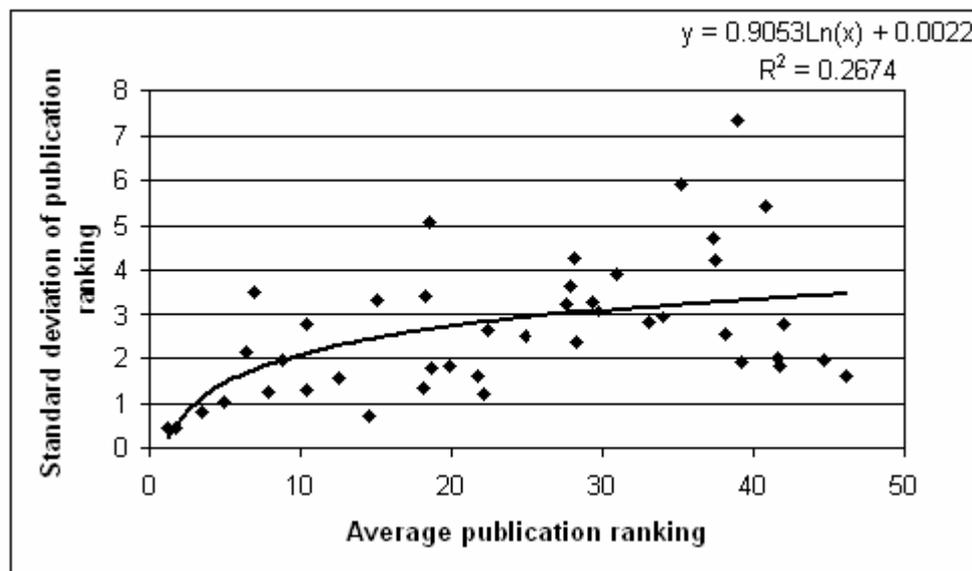


Figure 3. The relationship between the average publication ranking of universities and the standard deviation of their publication count ranking (London colleges excluded).

The equation of the approximate relationship is displayed in the upper right corner. The R^2 value gives the fitness of the approximate relationship (R^2 closer to 1 the more valid is the approximate relationship).

By considering the relationship between the average ranking and standard deviation of ranking we evaluate the stability/variability of the rankings. Figures 3 and 4 show the data for the rankings based on publication and citation counts. In both cases the standard deviation of rankings is approximately equal to the natural logarithm of the

average ranking. However, in the case of citation rankings ($R^2 = 0.5785$) the approximate relationship is much more valid than in the case of publication rankings ($R^2 = 0.2674$). In other words, in the case of publication count rankings the standard deviation of rankings is much more variable at any level of average ranking. This means that universities may change over time much more their ranking in terms of publication counts than in terms of citation counts at any level in the ranking. This implies that rankings based on citation counts are more stable and less variable than rankings of universities based on publication counts. The data also shows that as the average ranking increases the standard deviation of the rankings also increases, implying that universities closer to the bottom of the ranking lists change more their ranking position than those closer to the top of the ranking list. This means that while there are more likely changes in ranking of universities in the lower part of ranking lists, top universities change relatively little their ranking and it is much harder to go up and down in the ranking lists in the top of the lists than in the bottom of the lists.

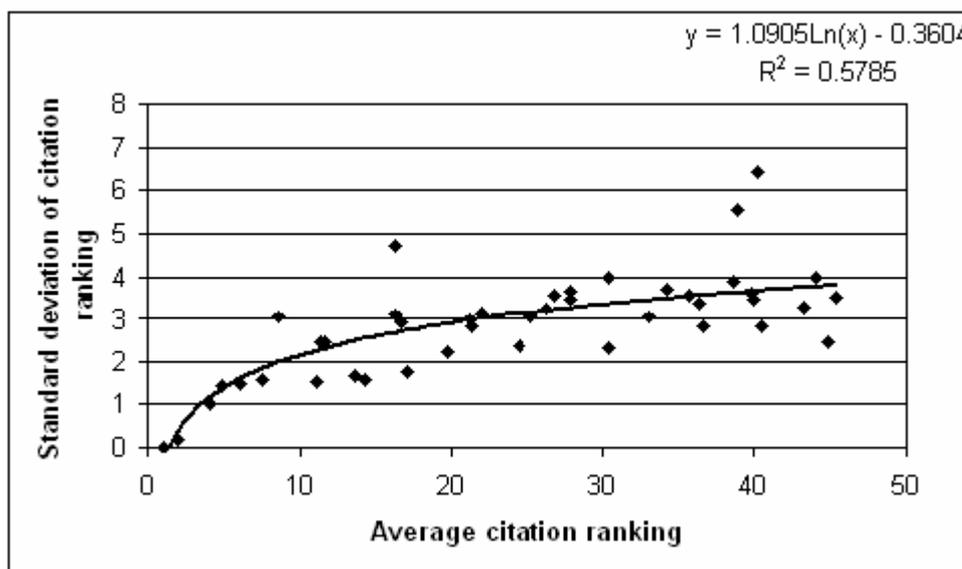


Figure 4. The relationship between the average citation ranking of universities and the standard deviation of their citation count ranking (London colleges excluded). The equation of the approximate relationship is displayed in the upper right corner. The R^2 value gives the fitness of the approximate relationship (R^2 closer to 1 the more valid is the approximate relationship).

In case of London colleges (Imperial, UCL, King's, Queen Mary, Royal Holloway) the relationship between the average ranking and the standard deviation of ranking is

different. These colleges went through a major consolidation process during the considered 31 years, including the incorporation of medical schools and formerly independent important research institutes. This means that their ranking changed very much in the period that we analyse, and that the standard deviation of their ranking is much larger than what could be expected based on their average ranking (i.e. the natural logarithm of the average).

The best universities (outside London) are those who have a low value average ranking and a low standard deviation of their ranking. This group is expectedly led by Cambridge and Oxford, and it also includes Edinburgh, Manchester and Bristol (however we note that in the last decade these were overtaken in the ranking lists by the two best London colleges – Imperial and UCL). Glasgow and Birmingham are two universities which drop down from the top group to the follower level, because of their too high standard deviations in rankings (they moved downward). Sheffield, Nottingham and Southampton constitute the core of the main follower group, with Liverpool and Leeds being the main downward movers within this group.

Overall the main upward movers are the top London colleges, Imperial, UCL and King's (to a good extent this is due to their mergers with medical schools and research institutes). They are joined as main upward movers by Bath, Durham and York, smaller size universities, with increasingly good performance in research output. The main downward movers are led by Sussex, which dropped very much in the ranking between 1970 – 2005 (from 9th position in 1975 to the 20th position in 2005 according to citation counts, and from 12th position in 1975 to the 28th position in 2005 according to publication counts) – a possible reason behind this could be a change in the research domain mix, by moving more into areas of social sciences, arts and humanities and leaving some areas of sciences. Other main downward movers are Salford, Reading, Hull, Stirling and Strathclyde.

3.3. Market share dynamics

We calculated the market shares of each university in each year within the total markets of publication and citation output of the considered universities. An alternative way to look at the dynamics of the academic research output is to analyse the evolution of market shares of universities. While the ranking dynamics analysis hides the actual differences between consecutive ranks, the analysis of the market share evolution can identify finer grained processes of change in performance.

For all universities we calculated their average publication and citation market share in three ten year periods (1975 – 1984, 1985 – 1994, and 1995 – 2004) and then we calculated the slope of the best fitting line defined by these three values. This slope value indicates whether these universities are on an increasing market share trend over these 30 years or rather on a decreasing market share trend. We calculated the trend slopes using ten year average market shares in order to avoid the noise effects of small yearly changes in market shares. We also calculated the average market share for publications and citations for each university for the whole 30 year period.

First we analysed the relationship between the slope values calculated for publication and citation market shares. The data is presented in Figure 5. The data shows that increase in publications market share (i.e. positive slope value) happens together with an increase in citations market share, and similarly decreasing market share in publication goes together with decreasing market share in citations.

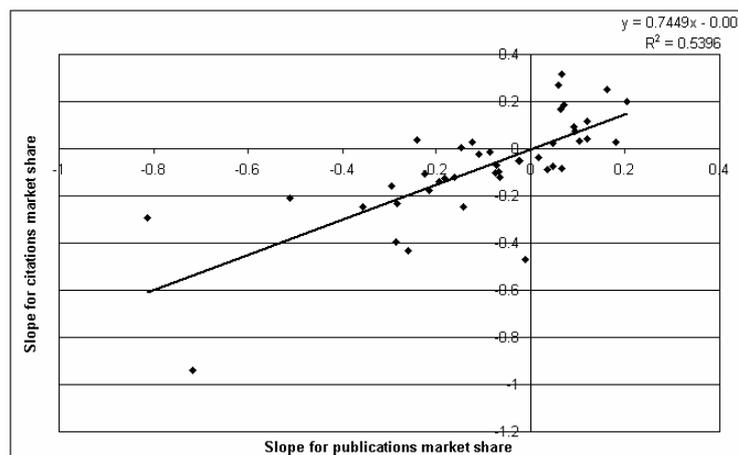


Figure 5. The relationship between change trends in publication and citation market shares (data for top London colleges, Oxford and Cambridge is not included). The approximate relationship between the two slope values is represented by the fitted line, of which equation is given in the upper right corner of the figure (the R^2 value indicates how good the approximate relationship fits the data – value closer to 1 indicates a better fit).

Further we analysed the relationship between the size of the market share and the value of the slope that indicates the change in the market share. Our data (see Figures 6 and 7) shows that larger the market share of a university it is more likely that its market share decreases in the considered 30 year period. At the same time our data identifies a group of universities with smaller market shares, which appear to steadily

increase their market shares. These universities are on the way to challenge the market dominance of universities with larger but falling market shares.

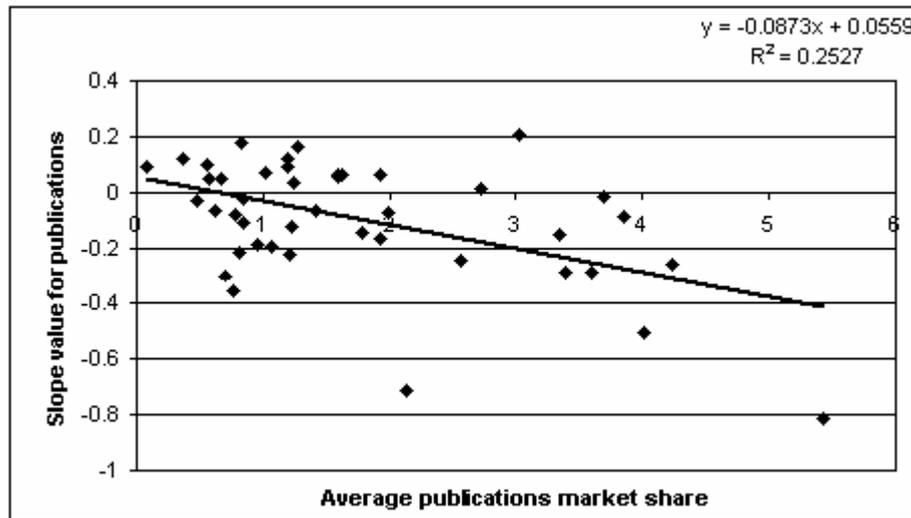


Figure 6. The relationship between the size of publications market share and the slope value calculated for publications market shares (data for top London colleges, Oxford and Cambridge is not included). The best estimated linear relationship is represented by the line. The equation of the best fitting line is displayed in the upper right corner – the R^2 value indicates the how good is the fit between the estimated relationship and the data, closer the R^2 value to 1 the better is the fit.

In case of Cambridge the general trends are valid, i.e. the market shares of Cambridge are decreasing, especially in the citations market. In case of Oxford, there is some decrease in their citations market share, however there is an increase in their publications market share. At the same time, both universities have much higher market shares than the rest of the universities, which makes them exceptional cases. Similar to the case of ranking analysis London colleges constitute exceptional cases. The top colleges (Imperial, UCL, King's) increased very much their market share (i.e. their slope values are very positive) both in the publications and citations market during the analysed period (1975 – 2005). As we already pointed out this is most likely due to the consolidation process of London colleges that involved mergers with medical schools and research institutes.

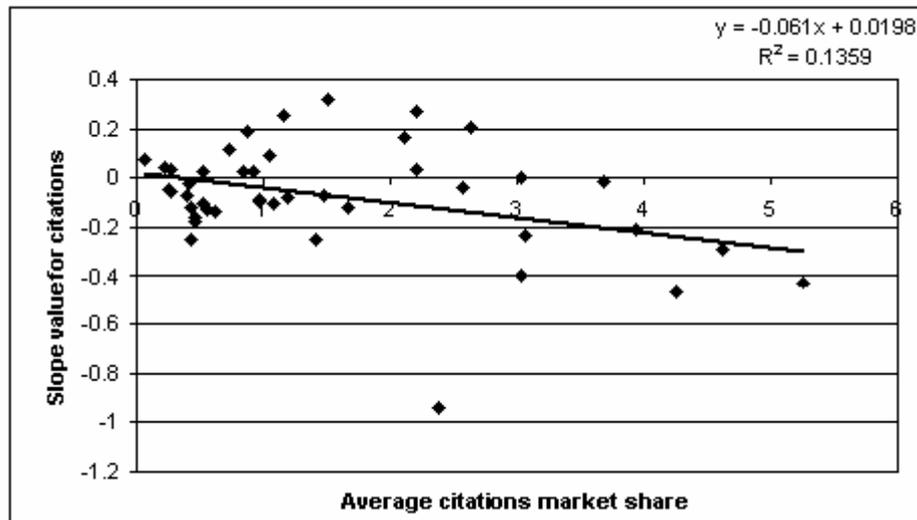


Figure 7. The relationship between the size of citations market share and the slope value calculated for citations market shares (data for top London colleges, Oxford and Cambridge is not included). The best estimated linear relationship is represented by the line. The equation of the best fitting line is displayed in the upper right corner – the R^2 value indicates the how good is the fit between the estimated relationship and the data, closer the R^2 value to 1 the better is the fit.

The group of universities which have large but decreasing market shares in both publications and citations includes the large civic universities, like Manchester, Edinburgh, Glasgow, Sheffield, and Leeds. The group of smaller follower universities with growing market shares in publications and citations is led by Durham, York, Bath, St Andrews and Exeter. We note that Nottingham constitutes an exception, being a university with large market share which increased its market share over the 30 year period. Other notable exceptions are Dundee and Leicester, which had a peak period in the middle of the 30 year that we analysed (early 90s for Dundee, late 80s for Leicester), and show overall increase in their market share, however in the last decade they follow the pattern of large universities, decreasing their market shares.

4. Discussion

In this section we discuss three issues: (1) what kind of research output is what we measure in our study, (2) the mechanisms that drive the gaining and losing of places in the rankings and in terms of market shares.

4.1. What do we measure ?

As we noted in the analysis section the data that we measure is dominated very much by publications and citations in sciences (i.e. natural and medical sciences). This means that our results mostly reflect the research output performance of universities in sciences (especially in terms of citations), and reflects to much less extent their performance in social sciences, arts and humanities. This also means that in the context of our data universities of which strengths are in social sciences or arts and humanities may appear to be performing less well than they actually may do. On the other side this means that the universities that we found as performing well are doing this most likely in areas of sciences.

Normal science is defined by Kuhn (1996) as the science which builds on a well-established theoretical core, and mostly consists of small advances complementing this core little-by-little. The rate of expansion of published normal science is domain specific, and essentially depends on how easy is to find new complementary statements or experimental results that qualify as publishable research output. In some purely theoretical sciences this might be difficult (e.g. mathematics), while in other more experimental sciences it may be easier to produce results that fit the established core of the science and still contain enough novelty to make the result publishable (e.g. molecular biology).

We believe that a large part of today's sciences (natural and medical sciences) are mature sciences based on well established core knowledge, which produce mostly output that qualifies as normal science. In particular, in our view, areas of normal science that are able to produce high volumes of output are likely to dominate the publication and citation output in sciences. Consequently, we believe that most of our measured data relates to normal science produced in these areas of sciences. This means that our results are about the analysis of high volume normal science produced in areas of natural and medical sciences, and the those universities identified as best performing according to various aspects of the analysis are the universities which perform the best in the generation of this kind of science.

Kuhn (1996) defines revolutionary science the scientific results that change the paradigm of a science, leading to reinterpretation of earlier results, and possibly to the discarding of a part of earlier results. Revolutionary science may happen at a deep level and large scale (e.g. the introduction of relativity theory in physics) or may happen more superficially at a smaller scale (e.g. the discovery of generation of new

neurons in brains of mammals). It is more likely for revolutionary science to happen at the more superficial smaller scale level. Although revolutionary science is likely to spark the expansion of related scientific output (i.e. reinterpretation of older results, generation of new results according to the new paradigms), the amount of this emerging science output is likely to be smaller than the amount highly productive normal science. Consequently, it is likely that revolutionary science output is overshadowed by large volume normal science output. An implication of this is that the output of universities in most cases is likely to be dominated very much by normal science output, and the scientometric data is likely to not emphasize the presence of revolutionary science. This means that primary analysis of scientometric data is not particularly sensitive to variation in revolutionary science output of universities, and our results are likely to not capture effects of changes in revolutionary science output. However, we note that it is possible that the best universities have many groups working in areas of science where they produce revolutionary science, and in the case that many of these groups are in the fast expanding phase of revolutionary science, it is possible that their output contributes significantly to the total output of the university. Generally we think that many large universities have groups generating revolutionary science, but if these groups are not sufficiently many their effect on the total output will be relatively minor. It is possible that changes in the market share of publications and citations are due to a good extent to the presence of groups generating revolutionary science in the fast expansion phase, and the turning of these groups over time into leaders in newly formed normal science areas with high output generation capacity. While in the case of smaller size universities such groups may help relatively easily the university to improve its output market share, in case of larger universities many such groups are likely to be required for an increase in market share, and it is more likely that the presence of such groups will just make them able to keep their market share.

4.2. The mechanisms behind gaining and loosing

As we noted earlier the dynamics in rankings represents a coarse grained dynamics of British academic science. The finer grained details of the dynamics are more likely to be captured by the analysis of the market share dynamics. While the ranking dynamics analysis provides a robust picture of main movements, identifying the main upward and downward movers, the market share dynamics offers a less clear and

more detailed version of this picture, pointing out possible mechanisms that drive the dynamics.

In the previous discussion sub-section we pointed out that in our view a large part of the research output that is produced is due to areas of normal science producing large volumes of output (e.g. molecular biology). As science areas mature and pass the transition from the stage of revolutionary science to normal science their methodologies and techniques become increasingly standardised, the relevant publishing standards become well established, the required equipment becomes cheaper and more reliable, and more scientists with specialist knowledge become available. In addition the electronic availability of scientific papers, and long-distance collaborations made possible through the Internet, facilitate the fast development of collaborative networks and make possible for any scientist to have informal and formal collaborations with leaders of their field (Adams et al, 2005). All these imply that it becomes relatively easy for a university to establish a new department or research group producing output in a mature science area, there will be relatively many universities with research output in this area, and the productivity difference between junior and senior scientists becomes smaller and this difference shrinks and disappears fast as the junior scientist becomes more senior. These mean that in areas of mature normal science it is likely that current market leaders loose part of their market share, while followers catch up with the leaders. Considering that most current science is in the mature normal science stage, this means that it is expected that universities with large volume output will slowly lose their market share, while universities with smaller volume output will gain market share (see Figures 6 and 7).

While in case of normal science followers are likely to catch-up with leaders in terms of research output measures (e.g. paper and citation counts), in case of science areas in the revolutionary stage we expect to see the opposite. In this stage equipment is usually experimental, expensive and operating it needs high skill, direct collaboration with the founding fathers of the field may be critical for getting published and noticed, and scientists having a deep understanding of the field are scarce. These imply that the few places which have the pioneering research groups of the field are likely to increase their lead in field specific scientometric measures. However, as we pointed out, it is also likely that the output produced in the emerging field will be small compared to the output of fields dominated by normal science. It is also possible that the field becomes relatively quickly accepted as an established field,

providing a large volume original lead for early entrants of the field in the early stage of the maturation to normal science. These imply that universities harbouring many groups developing revolutionary science may gain significantly in output terms from their presence, and this may help these universities to increase their overall market share (especially in case of universities with smaller research output) or to keep their market share at a stable level (in case of universities with large research output). Having many such groups may be indeed the critical feature for large universities to keep their market share in the market of overall research output.

While the above described mechanisms can have significant impact on the evolution of market shares of a university, their impact on rank dynamics is likely to be much less. Market shares change much quicker than rankings, but over long time stable trends in changes in market shares can result in changes in rankings. This can be seen in our data in the case of Sussex, which gradually lost its market share, leading to the sliding down in the rankings as well. As we noted this may be caused by many factors, including the change of the science mix (i.e. moving towards more social science and arts and humanities), and possibly also by focusing on maintaining only groups which lead the development of revolutionary science, and not maintaining them after they turn into regular producers of normal science. Dundee and Leicester are examples of moving upward through nurturing revolutionary science, in both cases the revolutionary period was followed by quick sustained growth in market shares and some increase in ranking. Also in both cases, the growth period is followed by a period of shrinking market share, during which other universities are catching up with them in their earlier revolutionary field.

At the same time the data shows that the main upward movers are the top London colleges, which merged with research institutes and medical schools, gaining overall market share and jumping upward in the rankings. This indicates that the big jumps in market shares and in rankings are the easiest to achieve by merging institutions, the model followed recently by Manchester, which merged with the UMIST.

5. Conclusions

We found that in agreement with expectations the publication and citation counts in the domain of sciences are much larger than in the domain of social sciences and arts and humanities. This means that scientometric analysis of general publication and

citation data is heavily dominated by output produced in natural and medical sciences. We also suggested that the largest part of this output is generated by mature sciences that produce normal science (Kuhn, 1996).

The analysis of ranking dynamics shows that the ranking in terms of citations counts is less variable than the ranking in terms of publications and also that the variability of both kinds of rankings increases as the rank values increase (i.e. towards the bottom end of the rankings). The biggest upward changes in rankings are due to mergers between research institutions (e.g. top colleges in London merged with medical schools and research institutes). The biggest downward changes in rankings may be due to changes in the science mix that a university has, especially if the composition of the mix changes in the favour of less productive areas of research (i.e. social sciences and arts and humanities).

While the ranking positions change little and the changes are usually very slow, the dynamics of market shares shows the trends in changes in more detail. The market share dynamics shows that universities with large volume output in most cases slowly lose their market share, while universities with medium size output volume are more likely to gain market share.

Our interpretation of the mechanisms behind these changes is based on the transition of science fields from the revolutionary science stage to the normal science stage, according to Kuhn's (1996) definition of revolutionary and normal science. While during the revolutionary stage the leaders in the science field are likely to increase their output market share, during the normal science stage it is more likely that followers catch-up with the market leaders. Considering that most of the current research in sciences is in mature fields that produce normal science output, we believe that it is not surprising that we see that many leading universities are losing market share, while followers are catching up with them. At the same time the proposed mechanism suggests that top universities may stay at the top, if they have enough many research groups developing fields of revolutionary science. It is also implied that having such groups may even help top universities in growing their market share, and in the case of follower universities such groups may speed up the pace of their market share growth (see the cases of Leicester and Dundee).

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Appendix

1. The list of considered universities

#	University	#	University
1	University of Aberdeen	25	University of Leicester
2	Aston University Birmingham	26	University of Liverpool
3	University of Bath	27	University College London
4	University of Birmingham	28	London School of Economics
5	University of Bradford	29	Loughborough University
6	University of Bristol	30	University of Manchester
7	Brunel University	31	University of Newcastle upon Tyne
8	University of Cambridge	32	University of Nottingham
9	City University	33	University of Oxford
10	University of Dundee	34	Queen Mary
11	University of Durham	35	Queen's University Belfast
12	University of East Anglia	36	University of Reading
13	University of Edinburgh	37	Royal Holloway
14	University of Essex	38	University of Salford
15	University of Exeter	39	University of Sheffield
16	University of Glasgow	40	University of Southampton
17	Heriot-Watt University	41	University of St Andrews
18	University of Hull	42	University of Stirling
19	Imperial College London	43	University of Strathclyde
20	Keele University	44	University of Surrey
21	University of Kent	45	University of Sussex
22	King's College London	46	University of Ulster
23	Lancaster University	47	University of Warwick
24	University of Leeds	48	University of York

2. The dynamics of rankings

A. Publication ranking

University \ Year	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	0	1	2	3	4	5	
University of Aberdeen	15	16	16	17	18	18	16	17	18	19	19	18	20	19	20	18	20	20	22	21	22	20	19	21	20	17	18	18	18	19	17	
Aston University Birmingham	33	33	34	31	32	37	38	33	35	36	37	39	40	40	40	43	43	44	44	47	45	46	47	47	47	48	46	46	45	46	43	
University of Bath	36	38	36	36	38	38	37	35	36	31	30	33	34	32	36	33	30	30	29	32	31	30	32	34	34	33	32	30	30	30	31	
University of Birmingham	6	6	6	6	5	6	25	6	6	6	6	7	6	6	7	5	5	5	5	5	7	8	8	7	5	6	8	8	7	9		
University of Bradford	26	27	27	28	35	39	31	39	40	39	38	36	37	37	37	37	37	39	39	41	39	38	40	40	39	41	45	43	40	40	42	
University of Bristol	7	11	8	7	10	8	7	9	8	7	8	8	9	9	9	5	9	7	8	7	7	6	7	9	9	7	8	6	7	8	7	
Brunel University	39	39	39	39	42	41	44	42	41	40	41	41	39	41	39	40	38	40	38	39	38	40	39	39	38	38	37	36	36	38	35	
University of Cambridge	1	1	1	1	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1	1	1	2	2	1	2	1	2	2	1	1	2	
City University	41	43	42	41	44	44	42	44	44	43	47	46	46	46	45	44	43	45	44	46	45	44	45	49	47	48	44	47	47	45	45	
University of Dundee	20	24	26	29	27	26	21	24	23	21	19	18	20	19	21	21	19	19	23	21	23	21	23	23	23	23	22	25	24	24	24	
University of Durham	23	23	20	20	23	22	20	21	21	22	23	22	23	22	22	22	22	21	25	23	25	22	22	18	20	19	20	21	20	21	21	
University of East Anglia	18	20	23	25	22	23	27	25	27	25	29	24	28	26	29	25	28	31	31	34	33	33	33	32	32	32	33	31	31	32	30	
University of Edinburgh	4	4	5	5	7	5	4	4	4	4	5	5	5	4	4	4	4	4	4	4	5	4	6	6	6	6	7	7	6	6	6	
University of Essex	34	35	35	37	40	40	40	40	39	41	40	37	38	39	38	35	36	33	36	37	37	37	37	36	36	36	42	41	41	42	42	41
University of Exeter	32	34	33	32	33	35	35	34	28	32	33	32	32	31	26	31	24	26	26	27	26	27	26	28	26	29	28	26	27	27	27	
University of Glasgow	5	5	4	4	4	4	5	5	5	5	4	4	4	4	5	6	8	6	6	6	8	9	9	7	8	8	9	9	10	11	11	
Heriot-Watt University	42	42	40	40	46	43	43	43	43	44	43	44	43	43	43	42	42	38	41	40	42	42	42	41	41	40	39	39	39	44	40	
University of Hull	22	25	25	26	26	30	26	29	26	26	27	30	33	35	33	32	35	32	34	35	36	34	34	33	33	34	35	33	33	33	34	
Imperial College London	50	47	48	44	13	11	10	10	12	11	11	10	10	10	12	15	15	12	12	11	6	4	5	5	3	10	4	3	3	3	3	
Keele University	47	48	43	47	49	49	50	50	50	51	51	50	50	51	51	50	50	50	51	51	50	48	50	51	51	51	51	51	51	51	50	50
University of Kent	28	29	30	30	31	31	33	30	31	34	34	36	36	36	34	36	34	35	37	33	32	35	35	35	35	39	38	38	38	37	36	
King's College London	43	40	44	46	15	13	11	12	11	12	14	13	13	14	13	13	12	15	15	14	12	14	14	14	13	11	10	11	10	9	8	
Lancaster University	21	26	28	23	24	25	22	26	24	27	24	26	26	29	27	29	31	25	28	28	28	26	31	31	31	31	31	31	32	31	33	
University of Leeds	9	7	7	8	6	7	6	7	7	8	7	11	8	8	7	8	6	8	9	12	10	10	10	11	11	9	11	10	12	12	12	
University of Leicester	17	18	19	19	20	20	17	19	20	20	20	20	19	18	18	20	18	18	16	16	17	18	17	17	17	18	17	17	16	17	18	
University of Liverpool	10	10	10	11	8	10	9	8	10	9	6	6	7	8	9	7	10	7	9	9	12	12	13	14	14	14	14	15	15	14	15	
University College London	8	8	9	10	43	47	46	47	46	45	45	45	44	45	47	45	45	33	17	14	8	6	3	4	3	3	4	4	4	4	4	
London School of Economics	44	45	46	45	34	27	28	28	29	35	25	28	29	30	31	28	32	36	36	36	40	39	37	36	40	36	36	42	37	39	39	
Loughborough University	38	36	37	35	39	36	39	38	37	37	35	35	34	35	34	33	34	32	30	35	36	38	37	37	44	43	47	46	43	46	46	
University of Manchester	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	5	4	5	5	5	5	
University of Newcastle upon Tyne	31	15	12	14	12	14	12	13	14	14	13	14	14	13	15	12	14	13	13	15	16	16	16	16	16	16	16	16	17	16	16	
University of Nottingham	13	13	15	13	14	16	14	14	15	13	12	12	12	12	10	10	11	11	11	10	13	13	13	10	10	12	12	13	13	13	13	
University of Oxford	2	2	2	2	2	2	2	2	2	2	2	1	1	2	2	2	2	2	2	2	2	1	1	2	1	2	1	1	2	2	1	
Queen Mary	45	44	51	43	36	28	36	37	34	29	31	29	27	28	30	39	47	48	49	46	34	32	29	29	30	26	30	35	35	37		
Queen's University Belfast	35	19	17	16	17	17	18	18	17	16	16	16	16	17	17	16	16	16	17	18	18	17	18	19	19	22	19	20	19	19	19	
University of Reading	16	17	18	18	19	19	19	20	19	18	18	21	22	21	21	19	19	21	20	20	20	19	20	18	19	22	23	21	23	23	23	
Royal Holloway	46	46	52	48	47	46	47	45	45	46	46	47	48	47	47	46	46	46	46	45	47	47	45	43	45	44	45	44	45	47	47	
University of Salford	25	28	24	24	29	32	32	36	38	38	39	40	41	38	41	38	39	37	40	38	43	43	46	46	46	46	47	48	48	48	48	
University of Sheffield	11	9	11	9	9	9	8	11	10	9	10	9	11	11	11	11	10	9	10	8	11	11	11	12	12	13	13	12	11	11	10	
University of Southampton	14	14	14	15	16	15	15	15	13	15	15	15	15	15	14	14	13	14	14	13	15	15	15	15	15	15	15	14	14	15	14	
University of St Andrews	29	31	29	34	37	34	29	31	32	30	36	34	30	33	32	27	27	28	30	29	30	29	28	27	28	30	27	27	26	25	25	
University of Stirling	37	37	38	38	41	42	41	41	42	42	42	42	42	44	44	40	41	43	43	44	44	43	44	42	43	42	40	43	41	44	44	
University of Strathclyde	19	22	21	22	25	24	24	23	25	23	26	25	24	24	25	24	25	24	24	22	25	24	25	25	29	27	29	29	28	29	29	
University of Surrey	30	30	32	27	28	29	30	27	33	33	28	27	25	25	24	26	26	29	27	31	29	31	30	30	27	28	26	28	29	26	26	
University of Sussex	12	12	13	12	11	12	13	16	16	17	17	17	16	16	17	17	17	18	19	19	22	24	24	25	25	25	23	25	28	28	28	
University of Ulster	40	41	41	42	45	45	46	47	47	44	43	44	45	42	41	41	42	42	42	41	41	41	42	43	37	40	37	41	36	38		
University of Warwick	24	21	22	21	21	23	22	22	24	22	23	21	23	22	23	23	23	23	24	24	21	23	20	21	21	21	21	22	20	21	22	
University of York	27	32	31	33	30	33	34	32	30	28	32	31	31	27	28	30	29	27	25	26	27	28	27	26	24	24	24	24	22	22	20	

B. Citation ranking

University / Year	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	0	1	2	3	4	5	
University of Aberdeen	12	15	16	18	22	20	18	19	21	21	18	20	19	19	20	20	20	20	22	20	20	22	20	22	20	19	20	21	22	21	22	
Aston University Birmingham	34	36	35	34	40	38	36	31	36	32	34	39	38	38	40	37	36	38	36	42	41	38	42	44	41	45	45	43	45	42	42	
University of Bath	37	38	37	30	39	32	32	32	32	37	31	28	30	27	34	29	28	28	24	26	26	31	28	29	29	29	33	27	25	27	27	
University of Birmingham	6	8	8	8	7	10	23	9	10	9	10	9	7	11	6	7	5	8	5	6	9	9	9	9	8	8	8	10	9	7	9	
University of Bradford	22	28	27	31	37	40	35	45	40	43	40	43	40	35	36	36	40	41	46	43	42	42	39	43	42	42	43	44	42	40	39	
University of Bristol	5	4	5	4	4	4	5	6	6	3	4	6	5	8	5	5	7	7	7	7	8	8	7	7	7	7	7	6	8	8	7	
Brunel University	38	37	42	39	38	41	44	39	39	30	38	34	34	36	38	33	35	40	35	36	35	34	35	34	36	36	36	36	36	36	36	
University of Cambridge	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
City University	42	43	41	41	45	47	45	41	46	44	46	46	45	43	45	45	39	43	44	44	45	45	45	46	49	48	49	45	48	47	48	
University of Dundee	16	18	17	17	20	21	20	17	18	18	20	18	18	17	14	14	12	6	11	13	12	17	15	16	16	14	18	18	17	18	18	
University of Durham	20	21	22	22	25	26	25	24	24	23	24	26	22	20	25	19	19	21	21	23	21	19	22	19	19	20	19	16	19	17	13	
University of East Anglia	17	20	23	25	23	24	26	25	28	24	25	24	26	25	27	23	29	29	31	27	30	26	32	28	28	27	28	28	29	31	26	
University of Edinburgh	2	3	3	6	5	3	3	5	4	6	3	4	4	4	3	3	3	3	3	4	5	4	5	4	5	4	5	5	5	5	5	
University of Essex	30	35	34	33	42	36	37	34	34	41	41	37	32	41	31	35	34	32	34	34	37	37	36	36	39	40	37	38	38	43	41	
University of Exeter	36	33	36	35	36	36	33	44	36	34	36	33	35	32	35	32	31	30	32	32	33	33	30	32	32	29	30	28	32	28	28	
University of Glasgow	8	6	6	7	9	11	6	8	7	7	7	7	11	5	8	6	6	5	8	9	5	7	8	8	9	9	10	8	7	9	8	
Heriot-Watt University	41	42	32	38	43	42	39	42	41	42	37	41	41	45	41	38	43	36	37	39	40	41	41	42	44	41	41	41	37	41	46	
University of Hull	26	27	30	32	28	34	31	40	33	35	29	32	37	34	37	30	38	34	38	38	38	40	38	38	34	35	35	35	35	34	35	
Imperial College London	46	45	46	44	11	6	7	4	5	6	3	5	3	6	12	11	15	9	6	8	6	3	3	4	4	5	4	3	3	3	3	
Keele University	43	46	43	48	49	50	50	49	51	51	51	50	50	51	51	51	50	50	49	48	47	46	49	48	47	49	46	47	47	48	49	
University of Kent	35	31	31	37	27	33	41	37	31	31	35	36	36	42	33	42	32	37	39	33	36	36	34	35	38	39	38	37	40	38	37	
King's College London	44	40	47	46	12	7	8	7	8	8	8	11	9	14	9	10	11	16	17	12	10	11	11	12	10	11	9	9	10	10	12	
Lancaster University	32	32	33	29	33	29	27	33	29	33	26	30	31	31	30	26	30	26	29	31	28	29	30	31	33	33	32	34	33	28	32	
University of Leeds	11	10	10	10	6	9	9	11	11	10	9	10	12	9	13	9	9	12	14	16	16	14	13	14	12	13	15	12	13	16	16	
University of Leicester	19	22	18	20	17	16	15	18	19	17	13	17	14	16	16	17	17	17	16	18	17	18	16	18	18	17	16	20	16	16	17	
University of Liverpool	10	11	12	11	8	13	12	13	12	12	12	8	8	7	7	8	8	11	10	11	11	13	14	13	14	15	14	14	15	11	15	
University College London	4	5	4	5	31	45	40	36	42	36	33	35	33	30	32	39	33	33	19	5	7	4	5	3	3	3	4	4	4	4	4	
London School of Economics	48	47	49	43	46	37	43	30	37	45	42	44	43	44	44	44	42	44	43	41	44	47	44	47	47	47	47	49	44	49	44	
Loughborough University	40	39	39	40	44	39	38	43	43	40	39	38	42	39	42	40	37	35	33	35	34	35	37	40	40	43	44	46	46	45	43	
University of Manchester	7	7	7	3	3	5	4	3	3	5	5	4	6	3	3	4	4	4	4	4	4	3	6	6	6	6	6	7	6	6	6	
University of Newcastle upon Tyne	29	17	13	14	15	15	17	16	17	20	16	16	17	15	17	13	16	13	13	17	18	15	17	15	17	18	17	17	18	19	19	
University of Nottingham	15	14	15	13	16	17	14	15	16	14	15	12	13	10	15	15	14	14	12	14	14	12	12	11	13	12	13	13	14	15	10	
University of Oxford	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Queen Mary	49	41	51	47	26	23	29	26	13	16	27	21	24	29	24	34	47	48	50	37	25	27	25	27	27	21	25	31	34	35	33	
Queen's University Belfast	33	23	20	16	18	19	19	20	20	22	21	19	21	21	21	21	21	19	20	21	22	21	21	21	25	22	24	23	20	23	23	
University of Reading	18	16	19	19	19	18	16	22	22	19	19	22	25	22	19	22	23	22	23	22	23	23	24	24	23	25	26	25	26	26	29	
Royal Holloway	50	50	52	45	47	44	46	46	45	46	45	47	47	49	47	47	46	46	45	46	48	48	47	41	46	44	40	39	41	37	38	
University of Salford	28	30	28	28	32	30	34	35	44	39	43	40	44	40	43	43	44	39	40	40	43	43	46	45	45	46	48	48	49	46	45	
University of Sheffield	13	12	9	12	13	12	11	12	9	11	11	13	10	13	10	16	10	9	10	13	10	10	11	10	11	10	11	11	11	11	12	11
University of Southampton	14	13	14	15	14	14	13	14	15	13	17	14	15	12	11	12	13	15	15	15	15	16	18	17	15	16	15	12	13	14	14	
University of St Andrews	23	24	24	27	35	31	21	21	30	27	32	27	29	33	29	31	27	25	30	30	29	24	27	25	26	28	23	24	23	24	24	
University of Stirling	31	34	38	36	34	43	42	38	38	38	44	42	39	37	39	41	41	42	41	47	39	44	40	39	37	38	42	42	39	44	47	
University of Strathclyde	21	26	26	26	29	25	22	27	26	26	28	29	28	23	28	25	25	24	28	25	31	30	29	32	31	34	31	33	30	33	34	
University of Surrey	27	25	29	23	24	28	28	28	23	29	22	25	20	26	22	28	26	31	27	29	33	32	31	33	30	30	34	32	31	29	31	
University of Sussex	9	9	11	9	10	8	10	10	14	15	14	15	16	18	18	18	18	18	18	19	19	20	23	20	22	24	21	19	21	20	20	
University of Ulster	39	44	40	42	41	46	47	47	47	47	47	45	46	47	46	46	45	45	42	45	46	39	43	37	43	37	39	40	43	39	40	
University of Warwick	24	19	21	21	21	22	24	23	25	28	23	23	23	24	23	27	22	23	26	28	27	28	26	26	24	26	27	26	27	25	25	
University of York	25	29	25	24	30	27	30	29	27	25	30	31	27	28	26	24	24	27	25	24	24	25	19	23	21	23	22	22	24	22	21	

3. The dynamics of market shares

A. Publication market shares

University / Year	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	0	1	2	3	4	5	
University of Aberdeen	2.41	2.16	2.23	1.96	1.97	2.07	2.17	2.22	1.92	1.98	1.93	2.01	1.92	1.98	1.90	1.86	1.86	1.80	1.66	1.71	1.61	1.68	1.71	1.67	1.80	1.99	1.94	1.88	1.83	1.77	1.90	
Aston University Birmingham	1.06	1.01	1.00	1.12	1.06	0.97	1.04	1.06	1.06	0.97	0.88	0.78	0.76	0.75	0.66	0.63	0.55	0.53	0.48	0.53	0.44	0.39	0.42	0.40	0.41	0.43	0.43	0.46	0.47	0.50		
University of Bath	0.69	0.70	0.77	0.98	0.95	1.06	0.98	1.01	1.10	1.17	1.06	1.04	1.01	0.98	1.17	1.14	1.21	1.14	1.10	1.17	1.02	0.90	0.95	1.01	1.02	1.15	1.15	1.08	1.04			
University of Birmingham	4.61	4.63	4.29	4.31	4.26	4.04	4.14	3.97	3.88	3.85	3.89	3.83	3.88	3.93	3.92	4.10	3.93	3.83	3.87	3.79	3.74	3.71	3.78	3.86	3.83	3.60	3.58	3.61	3.58	3.60		
University of Bradford	1.28	1.26	1.25	1.27	0.96	0.94	1.12	0.99	0.84	0.77	0.83	0.80	0.88	0.84	0.84	0.77	0.79	0.68	0.68	0.61	0.72	0.70	0.70	0.65	0.65	0.64	0.53	0.59	0.58	0.56	0.53	
University of Bristol	4.58	3.67	3.99	3.95	3.45	3.67	3.60	3.41	3.58	3.64	3.50	3.50	3.62	3.41	4.00	3.62	3.67	3.59	3.84	3.81	3.63	3.62	3.78	3.68	3.88	3.77	3.70	3.73	3.79			
Brunel University	0.56	0.57	0.52	0.59	0.59	0.67	0.50	0.56	0.72	0.74	0.66	0.72	0.77	0.73	0.77	0.73	0.60	0.69	0.68	0.73	0.69	0.75	0.68	0.70	0.71	0.68	0.67	0.70	0.64	0.70		
University of Cambridge	8.04	8.45	8.58	8.32	7.70	7.36	7.74	7.29	7.92	7.78	7.71	7.54	7.42	7.81	8.69	9.02	9.06	9.06	9.55	8.85	8.41	7.88	8.23	8.18	7.20	8.07	7.88	7.66	7.88	7.93	7.39	
City University	0.45	0.39	0.38	0.58	0.52	0.51	0.54	0.42	0.51	0.59	0.39	0.44	0.44	0.51	0.52	0.53	0.54	0.53	0.48	0.47	0.51	0.44	0.31	0.44	0.37	0.46	0.40	0.47	0.43			
University of Dundee	1.50	1.44	1.26	1.27	1.32	1.35	1.55	1.38	1.44	1.72	1.86	1.85	1.94	1.92	1.92	1.79	1.81	1.77	1.61	1.63	1.54	1.65	1.61	1.64	1.51	1.42	1.41	1.44	1.34			
University of East Anglia	1.76	1.59	1.46	1.33	1.59	1.42	1.37	1.38	1.24	1.37	1.22	1.39	1.27	1.31	1.14	1.31	1.18	1.10	1.07	1.00	1.05	1.00	0.94	1.02	1.01	1.01	0.98	1.07	0.96	0.98	1.05	
University of Edinburgh	5.03	4.80	4.53	4.44	4.17	4.35	4.49	4.48	4.40	4.24	4.18	4.32	4.19	4.08	4.40	4.42	4.32	4.28	4.34	4.18	4.12	4.00	4.18	4.12	3.98	3.84	3.81	3.82	3.83	4.06	4.07	
University of Essex	0.91	0.84	0.79	0.88	0.66	0.81	0.85	0.84	0.85	0.73	0.76	0.83	0.78	0.80	0.87	0.83	0.98	0.87	0.82	0.85	0.80	0.82	0.68	0.74	0.63	0.62	0.61	0.57	0.52	0.53		
University of Exeter	1.14	0.94	1.04	1.11	1.02	1.00	1.06	1.06	1.19	1.09	1.07	1.08	1.10	1.14	1.29	1.16	1.38	1.27	1.27	1.30	1.27	1.22	1.37	1.36	1.32	1.28	1.31	1.38	1.29	1.22	1.24	
University of Glasgow	4.99	4.78	5.25	4.79	4.38	4.47	4.44	4.30	4.26	4.01	4.25	4.34	4.14	3.98	3.98	3.84	3.90	3.61	3.70	3.59	3.53	3.66	3.74	3.66	3.62	3.39	3.42	3.55	3.29	3.21		
Heriot-Watt University	0.44	0.46	0.46	0.58	0.50	0.56	0.51	0.48	0.55	0.49	0.51	0.56	0.62	0.59	0.62	0.69	0.58	0.73	0.65	0.64	0.56	0.55	0.56	0.62	0.60	0.65	0.66	0.63	0.61	0.49	0.59	
University of Hull	1.39	1.39	1.33	1.30	1.36	1.20	1.37	1.15	1.24	1.21	1.31	1.12	1.04	0.99	1.00	1.01	0.88	1.00	0.98	0.94	0.99	0.96	0.88	0.93	0.98	0.94	0.88	0.91	0.86	0.81	0.74	
Imperial College London	0.01	0.05	0.00	0.05	2.69	3.24	3.27	3.41	3.10	3.22	3.18	3.32	3.22	3.24	2.87	2.41	2.25	3.16	3.15	3.14	3.60	4.13	4.04	4.28	4.78	3.43	4.93	5.71	5.99	6.52	6.19	
Keele University	0.07	0.03	0.03	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.04	0.04	0.08	0.25	0.29	0.10	0.18	0.22	0.20	0.20	0.19	0.20	0.21			
University of Kent	1.25	1.21	1.16	1.13	1.14	1.19	1.09	1.11	1.13	1.07	1.00	0.90	0.96	0.90	0.97	0.85	0.96	0.95	0.87	1.14	1.08	0.88	0.84	0.87	0.78	0.70	0.67	0.65	0.66	0.69	0.67	
King's College London	0.28	0.50	0.02	0.03	2.63	2.93	3.14	2.99	3.13	2.98	2.81	3.19	2.97	2.87	2.87	2.69	2.85	2.55	2.49	2.73	3.09	3.15	3.07	2.92	3.12	3.26	3.35	3.33	3.52	3.41	3.61	
Lancaster University	1.40	1.27	1.24	1.43	1.40	1.37	1.52	1.32	1.32	1.21	1.41	1.35	1.30	1.19	1.19	1.21	1.33	1.29	1.11	1.12	1.08	1.11	1.12	1.08	1.13	1.06	1.02	1.00	0.95			
University of Leeds	4.26	3.92	4.05	3.84	4.26	4.04	3.94	3.68	3.62	3.59	3.75	3.30	3.67	3.74	3.85	3.58	3.84	3.50	3.39	3.10	3.33	3.37	3.57	3.32	3.30	3.47	3.26	3.39	3.31	3.14	3.19	
University of Leicester	1.77	1.68	1.80	1.81	1.68	1.79	2.06	2.00	1.74	1.88	1.91	1.82	1.92	1.82	1.99	1.80	1.92	1.84	2.12	2.02	2.03	1.99	2.03	1.96	1.97	1.95	2.08	1.86	1.87			
University of Liverpool	4.17	3.76	3.68	3.78	3.57	3.27	3.46	3.47	3.36	3.36	3.43	3.89	3.94	3.78	3.76	3.46	3.84	3.42	3.60	3.43	3.43	3.29	3.16	2.97	3.01	2.92	2.84	2.76	2.93	2.90	2.77	
University College London	4.44	3.82	3.94	3.80	0.56	0.20	0.36	0.25	0.36	0.45	0.45	0.50	0.57	0.53	0.42	0.47	0.45	1.03	2.13	2.78	3.63	3.84	4.51	4.72	5.01	5.32	5.39	5.33	5.45	5.78		
London School of Economics	0.19	0.15	0.01	0.04	0.99	1.31	1.28	1.18	1.19	1.04	1.39	1.19	1.26	1.17	1.13	1.20	1.06	0.95	0.94	0.85	0.63	0.70	0.81	0.78	0.62	0.78	0.76	0.61	0.67	0.57	0.59	
Loughborough University	0.64	0.77	0.75	1.02	0.88	0.98	0.98	0.92	0.92	0.93	0.99	0.96	0.98	1.03	0.96	0.95	0.99	0.95	1.04	1.23	1.01	0.87	0.78	0.75	0.73	0.60	0.55	0.40	0.44	0.50	0.41	
University of Manchester	6.22	6.56	6.46	6.51	6.01	6.03	6.24	5.90	5.86	5.72	5.62	5.65	5.55	5.60	5.60	5.86	5.48	5.22	5.55	5.16	4.84	4.48	4.50	4.31	4.12	4.15	4.04	4.16	5.05			
University of Newcastle upon Tyne	1.15	2.37	3.29	2.96	2.97	2.83	2.92	2.88	2.81	2.71	2.84	2.82	2.90	3.02	2.65	2.81	2.64	2.85	2.78	2.60	2.30	2.28	2.19	2.37	2.29	2.26	2.15	2.13	2.08	2.02	2.08	
University of Nottingham	2.86	2.77	2.49	3.05	2.67	2.53	2.74	2.79	2.81	2.96	2.95	3.29	3.13	3.10	3.10	3.10	3.23	3.20	3.26	2.99	3.16	3.12	3.34	3.36	3.25	3.22	3.12	3.17	3.04	3.17		
University of Oxford	7.10	8.02	7.45	6.98	6.65	6.91	7.59	7.75	7.71	7.70	7.56	7.82	7.91	7.76	8.50	8.73	8.80	8.62	8.68	8.36	8.37	8.03	8.25	7.91	7.76	7.78	7.71	7.82	7.36	7.72	7.41	
Queen's University Belfast	0.09	0.28	0.00	0.06	0.98	1.27	1.06	0.96	1.10	1.12	1.16	1.16	1.16	1.20	1.13	0.73	0.29	0.19	0.10	0.49	1.04	1.10	1.15	1.24	1.19	1.36	1.13	0.86	0.72	0.74	0.62	
Queens University Reading	0.83	1.63	2.12	2.13	2.05	2.21	1.87	2.20	2.15	2.51	2.46	2.37	2.20	2.17	2.02	2.21	2.20	2.18	2.03	2.07	1.94	2.05	1.81	1.76	1.68	1.83	1.80	1.76	1.77	1.65	1.79	
University of Reading	1.95	1.89	1.98	1.96	1.90	1.84	1.83	1.96	1.84	2.20	2.06	1.78	1.67	1.70	1.80	1.82	1.91	1.78	1.70	1.77	1.77	1.72	1.69	1.77	1.80	1.68	1.51	1.58	1.54	1.49	1.38	
Royal Holloway	0.09	0.09	0.00	0.01	0.26	0.41	0.36	0.38	0.42	0.41	0.35	0.27	0.17	0.15	0.36	0.47	0.43	0.43	0.49	0.37	0.43	0.50	0.54	0.51	0.47	0.40	0.38	0.39	0.47	0.41		
University of Salford	1.32	1.23	1.43	1.41	1.23	1.18	1.10	0.97	0.85	0.88	0.78	0.75	0.71	0.70	0.68	0.77	0.69	0.78	0.68	0.55	0.51	0.46	0.44	0.48	0.40	0.38	0.39	0.37	0.33	0.33		
University of Sheffield																																

B. Citation market shares

University 7 Year	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	1	2	3	4	5	
University of Aberdeen	2.75	2.09	2.02	1.69	1.34	1.65	1.68	1.83	1.60	1.54	2.09	1.43	1.57	1.56	1.46	1.54	1.53	1.73	1.54	1.47	1.64	1.37	1.66	1.49	1.78	1.77	1.61	1.61	1.41	1.47	1.48
Aston University Birmingham	0.60	0.52	0.52	0.66	0.59	0.52	0.61	0.73	0.59	0.72	0.68	0.50	0.60	0.51	0.46	0.51	0.53	0.49	0.52	0.40	0.28	0.40	0.28	0.32	0.28	0.32	0.28	0.26	0.24	0.30	0.25
University of Bath	0.52	0.41	0.50	0.79	0.65	0.69	0.77	0.68	0.71	0.61	0.86	0.95	0.84	1.18	0.67	0.89	0.97	1.01	1.24	1.11	1.04	0.93	1.12	0.92	1.06	0.95	0.77	1.04	1.20	1.03	0.82
University of Birmingham	4.56	4.50	4.06	4.31	3.89	3.57	1.25	3.58	3.24	3.56	3.28	3.65	3.80	2.96	4.00	3.68	3.98	3.82	4.61	3.98	3.50	3.62	3.64	3.64	3.88	3.58	3.73	3.16	3.64	3.87	3.60
University of Bradford	0.95	0.76	0.90	0.77	0.68	0.45	0.61	0.42	0.50	0.41	0.33	0.53	0.63	0.58	0.53	0.68	0.49	0.38	0.25	0.28	0.27	0.34	0.27	0.30	0.30	0.31	0.24	0.31	0.31	0.32	
University of Bristol	4.75	5.11	5.01	5.37	4.26	5.09	4.67	4.47	4.16	4.91	4.63	4.26	4.96	3.87	4.20	4.52	3.79	3.84	3.72	3.73	3.52	4.03	3.98	3.94	3.95	3.86	3.76	3.92	3.72	3.70	4.07
Brunel University	0.36	0.51	0.15	0.48	0.67	0.44	0.34	0.54	0.51	0.77	0.50	0.71	0.74	0.55	0.55	0.73	0.58	0.39	0.54	0.51	0.57	0.82	0.56	0.59	0.50	0.42	0.40	0.40	0.48	0.53	
University of Cambridge	13.88	13.44	13.95	13.24	12.20	12.26	12.39	12.30	14.95	11.71	12.31	11.98	11.94	12.61	13.59	12.27	12.99	13.82	12.63	12.81	11.61	10.73	11.19	10.02	11.21	10.96	10.60	10.62	10.90	10.65	
City University	0.19	0.24	0.16	0.27	0.34	0.28	0.30	0.50	0.32	0.36	0.21	0.23	0.23	0.38	0.26	0.32	0.50	0.32	0.29	0.26	0.26	0.24	0.23	0.21	0.17	0.18	0.17	0.22	0.15	0.16	0.15
University of Dundee	1.47	1.91	1.88	1.79	1.57	1.60	1.51	1.88	1.82	2.01	1.92	1.92	2.06	2.21	2.99	2.66	2.75	3.98	2.88	2.76	2.86	2.12	2.74	2.31	2.44	2.58	1.94	1.95	1.91	1.92	
University of Durham	1.02	1.42	1.14	1.26	1.13	1.14	1.14	1.08	1.26	1.12	1.19	1.13	1.31	1.54	1.17	1.66	1.86	1.53	1.57	1.24	1.41	1.57	1.57	1.86	1.89	1.72	1.90	2.31	2.03	2.63	
University of East Anglia	1.45	1.47	1.10	1.08	1.32	1.29	1.13	1.05	1.01	1.12	1.09	1.25	1.15	1.29	1.00	1.30	0.89	0.97	0.80	1.06	1.00	1.12	0.82	1.05	1.14	1.16	0.96	1.01	0.86	0.74	0.91
University of Edinburgh	12.95	6.13	5.30	4.61	4.23	5.56	5.15	4.48	4.55	4.47	4.23	5.04	5.09	4.47	4.83	5.57	5.50	5.78	5.98	5.02	4.79	4.71	5.08	5.28	4.76	4.72	4.56	5.19	4.92	4.77	5.32
University of Essex	0.71	0.53	0.59	0.70	0.49	0.63	0.59	0.64	0.66	0.46	0.54	0.74	0.69	0.80	0.66	0.74	0.82	0.78	0.73	0.66	0.84	0.84	0.78	0.86	0.82	0.82	0.88	0.92	0.93	0.68	0.82
University of Exeter	0.54	0.59	0.52	0.65	0.77	0.64	0.63	0.45	0.62	0.64	0.54	0.74	0.69	0.80	0.66	0.74	0.82	0.78	0.73	0.66	0.84	0.84	0.78	0.86	0.82	0.82	0.88	0.92	0.93	0.68	0.82
University of Glasgow	4.98	4.71	4.84	4.61	3.63	3.53	4.24	3.93	4.01	4.13	3.97	4.26	3.29	4.25	3.69	3.88	3.87	4.06	3.68	3.46	4.73	4.19	3.89	3.80	3.61	3.56	3.29	3.79	3.68	3.78	
Heriot Watt University	0.20	0.29	0.71	0.49	0.48	0.39	0.58	0.49	0.45	0.50	0.43	0.53	0.29	0.45	0.46	0.37	0.52	0.45	0.36	0.30	0.30	0.31	0.31	0.28	0.33	0.28	0.30	0.36	0.30	0.19	
University of Hull	0.78	0.94	0.73	0.75	1.06	0.66	0.87	0.54	0.67	0.63	0.96	0.75	0.68	0.66	0.56	0.76	0.50	0.53	0.41	0.46	0.42	0.37	0.36	0.37	0.57	0.55	0.47	0.55	0.54	0.60	
Imperial College London	0.00	0.07	0.00	0.00	0.02	3.23	4.46	4.14	4.90	4.30	4.26	4.90	4.73	5.23	4.01	3.05	3.03	3.80	3.92	3.59	4.32	5.11	5.40	5.60	5.91	4.00	6.07	7.36	8.36	8.08	7.80
Keble University	0.10	0.04	0.02	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.08	0.19	0.24	0.06	0.16	0.22	0.18	0.20	0.16	0.15	0.08	
University of Kent	0.55	0.66	0.72	0.52	1.08	0.68	0.57	0.56	0.73	0.74	0.58	0.63	0.68	0.42	0.72	0.39	0.63	0.51	0.41	0.64	0.49	0.52	0.56	0.48	0.41	0.36	0.37	0.40	0.32	0.38	0.40
King's College London	0.02	0.32	0.00	0.01	3.19	4.34	4.00	3.98	3.53	3.74	3.41	3.41	3.44	2.88	3.40	3.14	2.77	2.31	2.12	2.85	3.06	3.07	2.93	2.55	3.13	3.11	3.36	3.28	3.57	3.05	2.70
Lancaster University	0.63	0.61	0.64	0.85	0.87	0.80	1.13	0.65	0.86	0.65	1.08	0.85	0.62	0.82	0.90	1.09	0.86	1.07	1.00	0.91	1.01	0.99	0.87	0.84	0.81	0.80	0.83	0.67	0.81	0.70	
University of Leeds	2.90	3.68	3.48	3.62	4.22	3.73	3.45	3.21	3.23	3.03	3.36	3.51	3.11	3.50	3.03	3.49	2.71	2.65	2.40	2.36	2.48	2.87	2.47	2.81	2.87	2.76	2.55	2.78	2.66	2.28	
University of Leicester	1.34	1.25	1.75	1.54	1.78	2.13	2.32	1.87	1.68	2.09	3.09	2.20	2.53	2.44	2.78	2.12	2.46	2.12	2.42	2.22	2.25	2.05	2.46	1.98	2.21	2.13	1.73	2.30	2.04	2.03	
University of Liverpool	3.22	3.40	3.25	3.22	3.84	2.66	2.92	2.90	3.21	2.57	3.16	3.89	3.70	3.95	3.80	3.25	3.66	3.11	3.17	3.13	2.99	2.84	2.79	2.90	2.52	2.51	2.56	2.57	2.45	2.77	2.47
University of London	5.54	4.94	5.13	5.19	0.91	0.29	0.58	0.80	0.44	0.63	0.71	0.66	0.76	1.01	0.83	0.44	0.62	0.58	1.77	4.45	4.26	4.97	4.65	5.99	6.45	6.82	7.12	6.40	6.53	6.85	6.43
London School of Economics	0.00	0.00	0.00	0.02	0.32	0.60	0.35	0.84	0.57	0.28	0.41	0.31	0.40	0.35	0.26	0.34	0.42	0.27	0.31	0.31	0.26	0.18	0.23	0.20	0.18	0.20	0.20	0.13	0.26	0.13	0.21
Loughborough University	0.21	0.34	0.28	0.34	0.35	0.45	0.59	0.46	0.44	0.47	0.49	0.51	0.46	0.50	0.36	0.41	0.52	0.52	0.63	0.56	0.61	0.54	0.42	0.36	0.39	0.30	0.27	0.18	0.20	0.21	0.23
University of Manchester	4.46	4.63	4.24	5.59	5.45	4.77	5.08	4.90	4.88	4.44	4.49	4.76	4.44	4.62	4.84	4.73	4.93	5.33	5.03	4.92	4.52	4.48	4.34	4.25	3.94	4.07	3.73	4.05	4.23	4.25	
University of Newcastle upon Tyne	0.73	1.93	2.71	2.44	2.35	2.23	1.84	2.19	2.17	1.83	2.47	2.40	2.18	2.60	2.33	2.80	2.63	2.60	2.65	2.32	2.25	2.37	2.17	2.45	2.11	2.16	2.01	1.98	1.77	1.90	1.86
University of Nottingham	2.14	2.28	2.34	2.60	2.09	2.10	2.39	2.42	2.52	2.44	2.48	3.17	2.76	3.11	2.81	2.63	2.72	2.57	2.77	2.68	2.64	2.90	2.89	3.07	2.68	2.98	2.68	2.60	2.53	2.44	2.92
University of Oxford	8.88	11.29	12.12	10.47	9.75	9.17	11.43	10.40	9.97	9.75	10.69	9.45	9.90	11.12	11.16	11.43	11.94	10.97	10.13	11.43	10.40	10.88	10.59	10.30	9.57	10.61	10.60	10.40	9.36	10.18	10.62
Queen Mary	0.00	0.31	0.00	0.01	1.12	1.31	0.94	0.95	3.20	2.15	1.06	1.42	1.20	1.06	1.21	0.60	0.16	0.02	0.03	0.46	1.21	1.12	1.15	1.07	1.16	1.60	1.23	0.83	0.67	0.54	0.64
Queen's University Belfast	1.61	1.14	1.60	1.96	1.78	1.70	1.58	1.79	1.65	1.54	1.45	1.48	1.39	1.54	1.28	1.47	1.46	1.88	1.59	1.39	1.41	1.38	1.58	1.55	1.34	1.38	1.26	1.29	1.52	1.27	1.23
University of Reading	0.40	2.07	1.69	1.63	1.67	1.71	1.97	1.39	1.45	1.99	1.94	1.39	1.17	1.39	1.55	1.35	1.34	1.33	1.24	1.35	1.29	1.23	1.25	1.28	1.18	1.10	1.12	1.13	1.04	0.81	
Royal Holloway	0.00	0.00	0.00	0.02	0.32	0.35	0.26	0.31	0.33	0.26	0.28	0.21	0.10	0.03	0.15	0.25	0.21	0.20	0.27	0.25	0.14	0.12	0.19	0.33	0.26	0.28	0.29	0.35	0.31	0.43	0.38
University of Sheffield	0.74	0.68	0.84	0.92	0.89	0.77	0.63	0.62	0.62	0.51	0.46	0.46	0.38	0.46	0.26	0.37	0.33	0.43	0.37	0.33	0.27	0.22	0.22	0.26	0.26	0.28	0.19	0.14	0.14	0.16	0.19
University of Southampton	2.66	2.67	3.48	2.92	3.13	2.85	3.03	3.07	3.38	2.99	3.23	2.99	3.43	2.91	3.07	2.55	3.09	3.39	3.32	3.32	2.68	3.20	3.33	3.18	3.04	3.15	3.06	3.08	2.80	2.68	2.76
University of St Andrews	2.43	2.45	2.38	2.31	2.63	2.61	2.72	2.74	2.73	2.55	2.45	2.64	2.90	2.95	3.07	2.84	2.74	2.50	2.52	2.49	2.50	2.37	2.12	2.26	2.48	2.50	2.53	2.79	2.26	2.44	2.63
University of Stirling	0.91	0.98	1.05	0.90	0.77	0.77	1.28	1.53	0.81	0.99	0.74	1.08	0.87	0.68	0.96	0.74	0.91	0.93	1.00	1.21	1.13	1.22	1.18	1.18	1.05	1.18	1.27	1.33	1.23	1.22	1.18
University of Strathclyde	0.65	0.56	0.49	0.62	0.81	0.39	0.47	0.55	0.53	0.53	0.38	0.39	0.54	0.53	0.50	0.39	0.44	0.													