A bibliometric analysis of research by the Cambridge Neuroscience Strategic Research Initiative

Extended Summary

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Preface

This report summarises the key findings of a bibliometric analysis of research and researchers affiliated with Cambridge Neuroscience. The current document aims to serve as an extended summary of the study, intended for dissemination to interested parties. A more comprehensive report, with more detailed results of the analysis and detailed descriptions of the methods and data sources, was also submitted to Cambridge Neuroscience.

Cambridge Neuroscience is a strategic research initiative to connect multidisciplinary neuroscience research and teaching across the University of Cambridge and affiliated institutes. Its mission is to increase the 'fundamental understanding of brain function and enhance quality of life'.[1] It is a virtual centre of excellence with activities organized around five interrelated themes: Developmental Neuroscience, Cellular and Molecular Neuroscience, Systems and Computational Neuroscience, Cognitive and Behavioural Neuroscience, and Clinical and Veterinary Neuroscience.

This bibliometric analysis aims to help Cambridge Neuroscience assess research performance and collaboration dynamics, with a view to informing the future direction of the network.

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[1] As of 8 June 2015: http://www.neuroscience.cam.ac.uk/

[2] For more information on Science-Metrix, please see www.science-metrix.com

[3] For more information on RAND's quality standards, please see www.rand.org/standards/

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Extended Summary

Background and context

1. Cambridge Neuroscience is a strategic research initiative launched towards the end of 2007[4] to connect multidisciplinary neuroscience research and teaching across the University of Cambridge and affiliated institutes. As one of the strategic research initiatives of the university,[5] Cambridge Neuroscience exists as a 'virtual centre of excellence', with a mission to increase the 'fundamental understanding of brain function and enhance quality of life'.[6] Recognising that the field of neuroscience cuts across many areas, the initiative is organised around five themes, which span the boundaries of traditional university departmental structures. Members of the network engage in collaborations across departments as well as institutes, and the initiative thus provides an important focus for neuroscience research at Cambridge, facilitating the sharing of methodologies, technologies and ways of addressing conceptual issues in neuroscience research. The five core research themes within Cambridge Neuroscience are:
   - Developmental Neuroscience;
   - Cellular and Molecular Neuroscience;
   - Systems and Computational Neuroscience;
   - Cognitive and Behavioural Neuroscience; and
   - Clinical and Veterinary Neuroscience.

2. This bibliometric analysis aims to inform and support Cambridge Neuroscience in their strategic direction by providing evidence on the research performance of the network (and its constituent researchers and organisational units) and by exploring collaboration dynamics. More specifically, the report looks at:
   - the publication outputs and impacts of researchers affiliated with Cambridge Neuroscience, using seven levels of analysis: (i) the overall initiative (network) level, (ii) specific research themes, (iii) departments affiliated with the network, (iv) institutes affiliated with the network, (v) career stage/staff categories, (vi) individual researchers, and (vii) bibliometric fields[7];

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[4] As of 8 June 2015: http://www.neuroscience.cam.ac.uk/docs/LaunchProgramme.pdf

[5] As of 8 June 2015: http://www.cam.ac.uk/research/research-at-cambridge/strategic-research-initiatives-networks

[6] As of 8 June 2015: http://www.neuroscience.cam.ac.uk/

[7] Each analysable publication falls into a particular subject-based Web of Science (WoS) journal set. This could be any of the 22 fields from Science-Metrix's taxonomy in WoS.

- collaborations within Cambridge Neuroscience (i.e. among research themes, affiliated researchers and departments) and nationally and internationally; and
- the overall competitive position of Cambridge Neuroscience vis-à-vis other key national institutions active in neuroscience research.

3. Bibliometrics is the use of statistical methods to analyse patterns of scientific publication and citation. The various bibliometric indicators generated and analysed are based on counts of scientific publications and citations to publications by researchers currently affiliated with Cambridge Neuroscience that are indexed in Thomson Reuters' Web of Science (WoS) database.[8] The document types cover articles and reviews.

4. In the analysis, we used the following key bibliometric indicators (Table 1 below provides explanations of each):
- *for volume of outputs*: the number of papers published by researchers affiliated with Cambridge Neuroscience;
- *key indicators of scientific impact*: Average of Relative Citations (ARC) which shows impact across the research portfolio of Cambridge Neuroscience, and the percentage of Highly Cited Publications (% HCPs); these indicators are used as proxies for 'quality';
- *complementary indicator of impact*: Average of Relative Impact Factor (ARIF) which shows the citation impact of the journals Cambridge Neuroscience publishes in; ARIF is often used as a measure of the 'ambition' level of an entity in terms of the journals it targets;
- *for collaboration*: the number and percentage of collaborative papers (covering internal, national and international collaboration); and
- *for benchmarking*: the core indicators listed above were used to assess the competitive position of Cambridge Neuroscience vis-à-vis key national institutions active in neuroscience research.

Table 1. Bibliometric indicators used in the analysis

Bibliometric indicator	Explanation	
Number of papers	This is the number of publications at each level of aggregation (i.e. Cambridge Neuroscience as a whole, research theme, department, institute, researcher, career stage, and bibliometric field).[9]	Measure of scientific production
Average of Relative Citations (ARC)	This is a direct measure of the scientific impact of an entire publication portfolio based on paper citation counts, normalised to account for different citation patterns across fields and subfields of science and for differences in age of papers. When the ARC is above 1, it means that an entity scores better than the world average; when it is below 1, it means that, on average, an entity publishes papers that are not cited as often as the world average. This is a key 'quality' indicator (using citations as a proxy), along with HCP (see next entry).	Measures of scientific impact (proxies for 'quality')
Highly Cited Publications (HCPs) – absolute number and percentage	This is another citation-based indicator that measures research excellence based on the identification of 'top-performing' papers in a particular field. It refers to the proportion of publications that rank among the 10% most cited publications worldwide in the bibliometric database, normalised for age and for field and subfield variations in citation behaviour. Along with ARC, this is a key 'quality' indicator (using citations as a proxy).	
Average of Relative Impact Factors (ARIF)	This is an indirect measure of the expected scientific impact based on impact factors of journals in which papers are published. The ARIF score is normalised to account for different citation patterns across fields and subfields of science. It provides an indication of the visibility of research and can be used as a proxy for the 'aspiration' or 'ambition' of an entity. When the ARIF is above 1, it means that an entity scores better than the world average in terms of the types of journals it targets its publications in; when it is below 1, it is below the world average.	Measure of journal impact (proxy for 'ambition')
Internal collaboration	This refers to the number and proportion of publications involving at least two different Cambridge Neuroscience researchers, or at least two different departments, or at least two different research themes.	Measure of the level of collaboration activities
National collaboration	This refers to the number and proportion of Cambridge Neuroscience publications involving at least one researcher from the Cambridge Neuroscience network and at least one researcher from the other leading publishing United Kingdom organisations in neuroscience research.	
International collaboration	This refers to the number and proportion of publications involving at least one researcher affiliated with the Cambridge Neuroscience network and at least one researcher from another country.	

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[9] Unless specified, we have examined bibliometric performance based on the volume of analysed (rather than submitted) publications (i.e. based on the number of publications after the bibliometric matching process, as this is the number used to calculate impact indicators).

5. The key findings in this report are analysed and interpreted with the following timeframes and methodological considerations in mind:

- Cambridge Neuroscience was officially formed as a network in September 2007.[10] We conducted a pre- and post-2007 analysis of key bibliometric indicators to investigate any difference between performance across these two periods (i.e. between the periods 2003–2007 and 2008–2014, respectively).[11]

- The number of citations received by each publication was counted for the year in which it was published and for all subsequent years.

- The resultant bibliometric indicators of impact were normalised for field and age of publication so that direct comparisons can be made between individual entities (i.e. the performance of the different themes, departments, individual researchers, etc. can be compared with each other).

- The ARC and HCP impact indicators could only be computed for entities which have at least ten publications with relative citation counts.[12]

- It is important to note that Science-Metrix uses a minimum citation window of three years to compute the ARC and HCP indicators (i.e. year of publication plus the following two years), which, in the case of this report, results in these indicators not being computed after 2011. This is to ensure that enough time has elapsed since publication so that its impact can be assessed reliably.[13] The ARIF indicator, however, is computed up to 2014.

- Science-Metrix maintains a version of Thomson Reuter's WoS abstract and citation database of peer-reviewed literature, which contains the majority of scientific publications (including health and biomedical research) for the period 1980–2014. WoS currently indexes approximately 38 million records from more than 27,000 peer-reviewed journals (i.e. articles that are peer reviewed prior to publication), covering various fields of science (e.g. natural sciences and engineering) as well as the social sciences and humanities. WoS lists the references cited by each document it includes, allowing for internal coverage monitoring of the database and analysis of impact based on citations.

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[10] As of 8 June 2015: http://www.neuroscience.cam.ac.uk/docs/LaunchProgramme.pdf

[11] When data relating to the number of publications in particular are analysed, we present information for 2008–2012 to ensure a like-for-like five-year comparison with the 2003–2007 period; however, we also provide the most recent information for 2008–2014.

[12] Science-Metrix usually does not compute these indicators for entities with fewer than 30 papers with a relative citation score. However, given that data at the researcher level was submitted by Cambridge Neuroscience, this criterion was relaxed to include scores for entities with at least 10 papers with a relative score. Scores based on between 10 and 29 publications with relative citation scores are, nevertheless, highly prone to fluctuations because of extreme values, and particular caution is advised when analysing these results.

[13] The minimum three-year window was selected by Science-Metrix after in-house testing which demonstrated that a three-year window covered most of the citations received by a publication. While it would be even better to wait for more time so that a larger share of received citations can be taken into account (especially for publications from Social Sciences and Humanities, for which the citation process is slightly slower), the three-year citation window was selected as a good compromise between robustness of the analysis and the possibility to compute this indicator in time (e.g. a larger, five-year citation window would result in this indicator not being computed after 2009, leaving even less publications for the global impact analysis).

- Each publication submitted for bibliometric analysis could fall into a particular subject-based WoS journal set, and this could be any of the 177 subfields from Science-Metrix's taxonomy in WoS. Each subfield is itself assigned to one of 22 specific fields. During the analysis, each publication is assigned to only one subfield and thus to only one field.[14]

Key findings

6. In this section, we outline the key findings of the bibliometric analysis by level of aggregation. These are discussed in turn below.

Cambridge Neuroscience – overall performance and benchmarking vis-à-vis other leading UK institutions active in neuroscience research

7. Researchers affiliated with Cambridge Neuroscience published a total of 9,755 bibliometrically analysable unique publications in the 2003–2014 period[15] (Table 2), and scientific output has steadily increased over the years under investigation. The relative growth rate in publication output from 2003–2007 to 2008–2012 is 38%. Although we lack the information necessary to interpret this figure in the context of changes in the number of staff over time, the absolute number of publications suggests a vibrant and active research community.

8. Neuroscience research at Cambridge has sustained high academic impact over time. Based on the key indicator of bibliometric performance of the overall research portfolio (i.e. the ARC score), research by individuals currently affiliated with Cambridge Neuroscience has consistently had a substantially higher citation impact than the world average (approximately double). Furthermore, with a total of 959 Highly Cited Publications in the post-2007 period, Cambridge Neuroscience has approximately 2.5 times more articles than expected in the top 10% most highly cited ones. Cambridge Neuroscience is also performing above the world average in terms of its ARIF score (Figure 1 and Table 2).

9. This analysis provides an indication of the scientific performance of people currently active in neuroscience research who are affiliated with the Cambridge Neuroscience initiative. At this level of analysis, we do not observe major differences in scientific impact before and after the establishment of Cambridge Neuroscience as a network. However, more granular analysis (e.g. at the department and institute level) does show some differences over time (see below), both in impact trends and in the extent of research collaboration. Further qualitative analysis could help explore and capture the value that the Cambridge Neuroscience initiative adds to sustaining neuroscience research excellence at the University of Cambridge. It could also investigate which network activities provide the highest value for individuals, departments and institutes, as well as for the university as a whole (including niche actors).

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[14] Impact scores are then computed for each publication by normalizing its score with the average scores for all publications under the same subfield and published in the same year.

[15] It must be noted that because of collaborations, some of these publications involved multiple researchers across Cambridge Neuroscience.

Table 2. Comparison of the primary indicators for publication output and impact for Cambridge Neuroscience as a whole[16]

	Number of publications	Average of relative citations (ARC)	Highly cited publications (HCP 10%)		Average of relative impact factors (ARIF)
			Number	%	
2003-2014	9,755	2.02	1,878	25.1%	1.53
2003-2007	3,613	2.03	919	25.5%	1.48
2008-2014	6,142	2.02	959	24.8%	1.56

Figure 1. Trend in the primary indicators of publication impact (Average of Relative Citations, percentage of Highly Cited Publications and Average of Relative Impact Factors) for Cambridge Neuroscience as a whole

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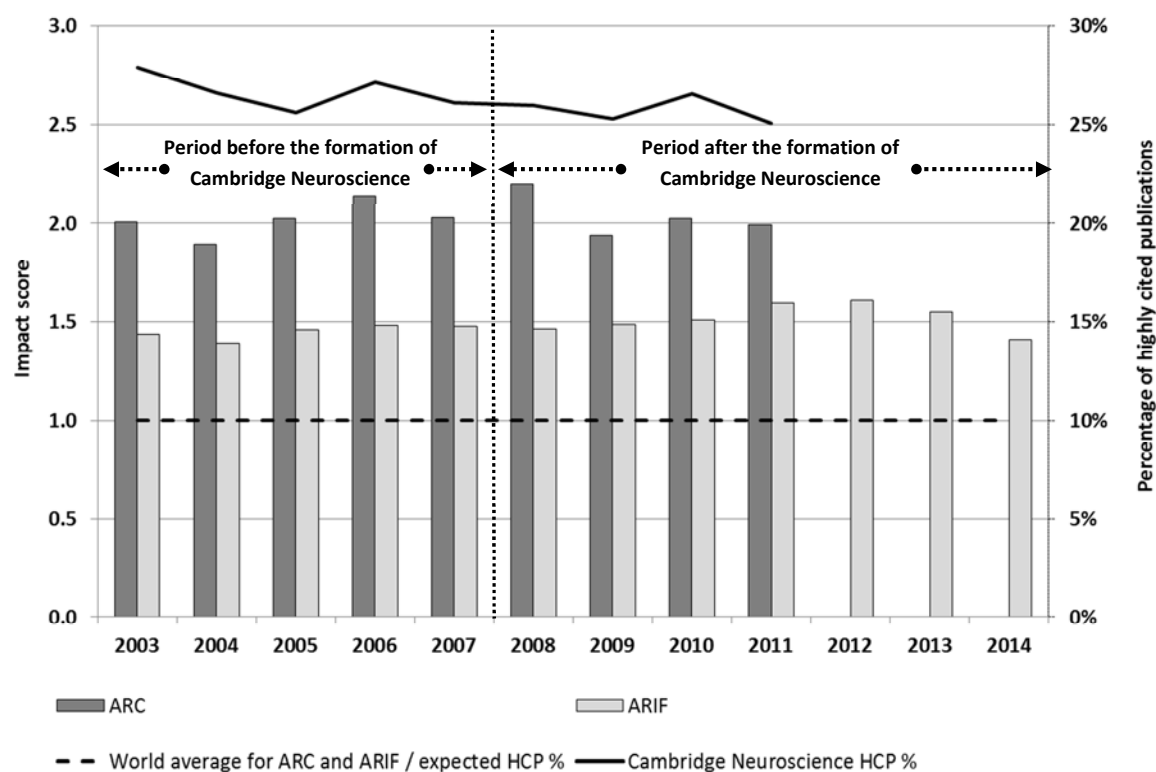
[16] As noted previously, Science-Metrix uses a minimum citation window of three years to compute the ARC and HCP indicators (i.e. year of publication plus the following two years), which results in these indicators not being computed after 2011.

10. When compared with 49 other leading institutions[17] in the UK publishing in the area of neuroscience, Cambridge Neuroscience has the highest citation impact for its overall research portfolio (i.e. the ARC score) (Table 3), as well as the highest percentage of Highly Cited Papers. In terms of the volume of outputs, Cambridge Neuroscience is second in the top 50 list, behind University College London (Table 4). Cambridge Neuroscience also seems to be the most ambitious in terms of the profile of journals it targets (i.e. in terms of the ARIF score).

11. It is interesting to observe that some niche players and non-academic actors also do particularly well based on citation impact (e.g. London School of Hygiene & Tropical Medicine, GlaxoSmithKline).[18]

12. To demonstrate the relationship between citation impact and publication activity in the post-2007 period, a plot of the ARC score expressed as a function of the volume of publications for Cambridge Neuroscience and the ten institutes specifically selected for benchmarking by Cambridge Neuroscience is presented in Figure 2. All the institutes have more than 2,000 publications, and they have citation impacts that are above the world average. Four entities have more than 5,000 publications as well as ARC scores that exceed 1.70, namely, Cambridge Neuroscience, University of Oxford, University College London and King's College London.

13. It is important to note that we do not have any information regarding the relative sizes of the institutions being compared. Therefore, the extent to which research output is linked to the absolute number of staff as opposed to increased productivity (outputs/staff) is not known, and the various results presented in the benchmarking analysis need to be interpreted within this context.

14. As a visual representation, a map presenting the key bibliometric indicators for Cambridge Neuroscience and the ten institutes selected by Cambridge Neuroscience for the benchmarking exercise is depicted in Figure 3.

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[17] To carry out the benchmarking exercise, a database of 'neuroscience' publications had to be created first. Using a set of Medical Subject Headings (MeSH) relevant to the field of neuroscience, publications indexed in Medline were retrieved and matched on the Web of Science. Specialised journals were added to this core dataset to cover publications that could have been missed by the MeSH term approach. In addition, expansions based on documents frequently cited by or frequently citing the core dataset of publications retrieved with the MeSH terms and specialised journals were performed to add publications to the final dataset (i.e. additional publications with a strong focus on neuroscience were identified that would have been missed by the MeSH term and journal approaches).

[18] It is plausible that industry publications involve academic collaborators.

Table 3. Comparison of the ARC values for the top 50 UK institutions publishing neuroscience research (the data are sorted by the ARC values achieved in the post-2007 period; the ten institutes selected by Cambridge Neuroscience for benchmarking are highlighted in grey)[19]

Top 50 UK institutions publishing neuroscience research	Average of relative citations (ARC)			Yearly trend (2003-2011)
	2003-2011	Pre-2007	Post-2007	
Cambridge Neuroscience	**2.02**	**2.03**	**2.02**	
London School of Hygiene & Tropical Medicine	1.84	1.70	1.96	
GlaxoSmithKline	1.77	1.63	1.94	
Birkbeck, University of London	1.59	1.26	1.90	
University of Cambridge*	1.80	1.72	1.88	
University of Oxford	1.80	1.73	1.86	
Medical Research Council	1.77	1.71	1.84	
University College London	1.66	1.61	1.71	
King's College London	1.59	1.48	1.70	
Imperial College London	1.59	1.49	1.69	
University of Glasgow	1.45	1.28	1.64	
University of Southampton	1.52	1.44	1.60	
University of Wales	1.40	1.36	1.59	
St George's, University of London	1.48	1.41	1.57	
Keele University	1.40	1.29	1.51	
University of London	1.47	1.42	1.50	
Newcastle University	1.44	1.39	1.50	
University of Bristol	1.37	1.26	1.48	
University of the West of England	1.44	1.41	1.47	
University of Aberdeen	1.49	1.51	1.47	
Queen Mary University of London	1.43	1.39	1.46	
Cardiff University	1.33	1.17	1.46	
University of Edinburgh	1.45	1.46	1.45	
University of Sheffield	1.35	1.28	1.43	
University of Manchester	1.38	1.33	1.43	
University of Bath	1.50	1.57	1.43	
University of St. Andrews	1.44	1.45	1.43	
University of Exeter	1.34	1.22	1.42	
University of Sussex	1.22	1.03	1.38	
University of Dundee	1.35	1.32	1.38	
University of Warwick	1.31	1.24	1.36	
University of Nottingham	1.30	1.25	1.35	
University of Plymouth	1.18	1.01	1.32	
Queen's University Belfast	1.13	0.96	1.32	
University of Abertay, Dundee	1.29	1.29	1.30	
University of Birmingham	1.19	1.12	1.25	
University of York	1.20	1.17	1.24	
University of Liverpool	1.25	1.27	1.22	
Sheffield Hallam University	1.19	1.19	1.20	
University of Leeds	1.18	1.17	1.20	
University of Reading	1.12	1.05	1.18	
University of Ulster	1.08	1.01	1.14	
University of Leicester	1.14	1.15	1.13	
Durham University	1.13	1.13	1.13	
University of Surrey	1.07	1.03	1.11	
De Montfort University	1.11	1.13	1.09	
Swansea University	1.03	1.11	0.97	
Aston University	0.84	0.79	0.91	
Liverpool John Moores University	0.96	1.03	0.90	
University of Hull	0.83	0.78	0.89	

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[19] The publication dataset for University of Cambridge, which appears as a separate entity from Cambridge Neuroscience in the benchmarking list, includes those papers that have at least one address from the University of Cambridge in the neuroscience dataset. This results in some overlap between the University of Cambridge and Cambridge Neuroscience.

Table 4. Comparison of publication activity for the top 50 UK institutions publishing neuroscience research (the data are sorted by the volume of publications in the period 2008–2012; the ten institutes selected by Cambridge Neuroscience for benchmarking are highlighted in grey)[20]

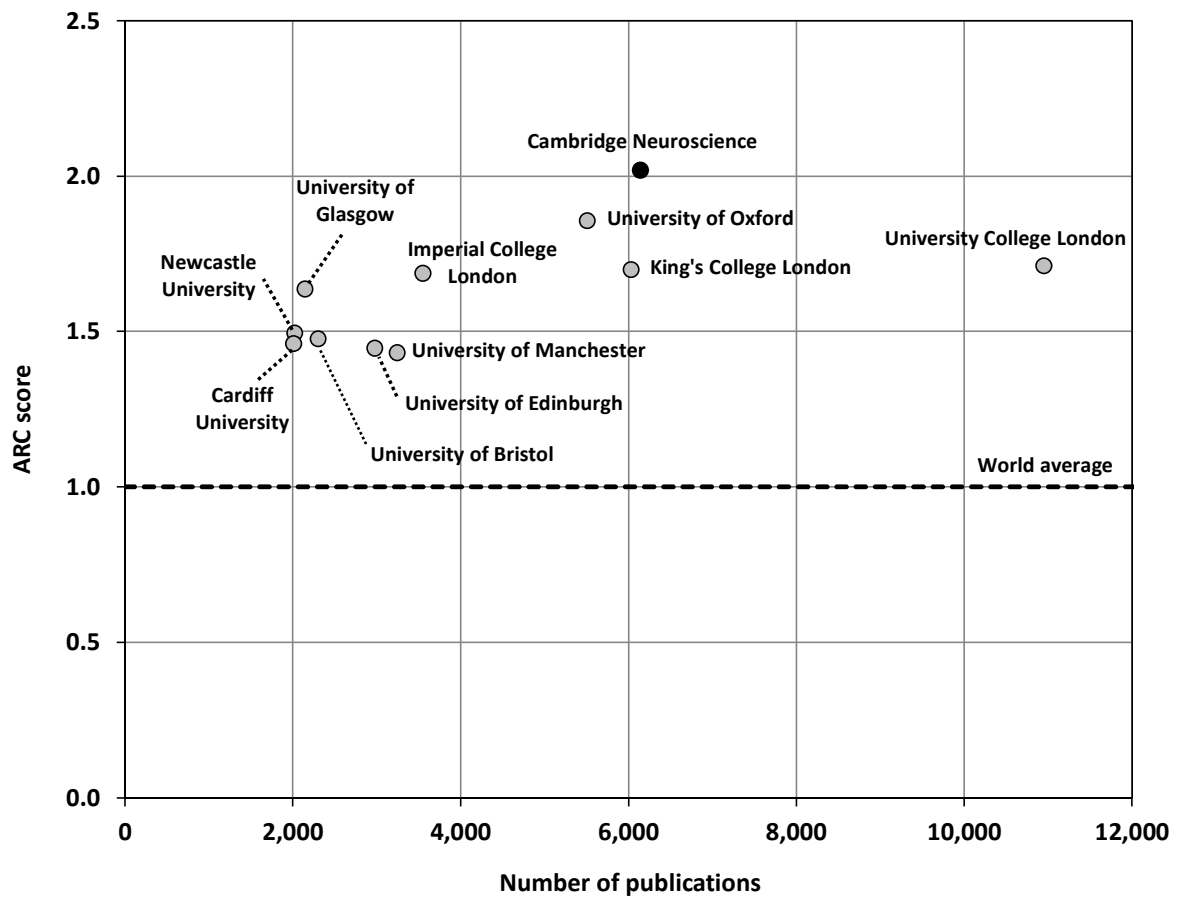| Top 50 UK institutions publishing neuroscience research	Volume of publications				Yearly trend (2003-2014)
	2003-2014	2003-2007	2008-2014	2008-2012	
University College London	18,218	7,266	10,952	8,689	
Cambridge Neuroscience	**9,755**	**3,613**	**6,142**	**4,970**	
King's College London	9,623	3,593	6,030	4,773	
University of Oxford	8,791	3,283	5,508	4,371	
University of Cambridge*	7,601	2,967	4,634	3,780	
Medical Research Council	6,323	2,412	3,911	3,190	
Imperial College London	5,924	2,373	3,551	2,873	
University of Manchester	5,258	2,013	3,245	2,622	
University of Edinburgh	4,876	1,899	2,977	2,419	
University of Bristol	3,875	1,572	2,303	1,912	
University of Birmingham	3,679	1,365	2,314	1,824	
University of Glasgow	3,666	1,518	2,148	1,738	
University of Nottingham	3,404	1,290	2,114	1,695	
Newcastle University	3,352	1,330	2,022	1,631	
Cardiff University	3,002	993	2,009	1,590	
University of Sheffield	2,497	999	1,498	1,161	
University of Liverpool	2,421	1,025	1,396	1,133	
University of Leeds	2,315	931	1,384	1,112	
University of Southampton	2,244	863	1,381	1,099	
Queen Mary University of London	1,804	664	1,140	895	
University of London	1,482	377	1,105	884	
University of Aberdeen	1,784	712	1,072	883	
University of Leicester	1,666	671	995	807	
GlaxoSmithKline	1,534	710	824	722	
University of Sussex	1,258	434	824	652	
University of Exeter	1,160	367	793	647	
University of Plymouth	1,139	419	720	590	
St George's, University of London	1,340	594	746	586	
University of York	1,146	425	721	559	
Queen's University Belfast	1,179	489	690	550	
University of Dundee	1,110	437	673	542	
University of Warwick	998	323	675	532	
Sheffield Hallam University	1,123	446	677	516	
Keele University	981	404	577	482	
London School of Hygiene & Tropical Medicine	850	289	561	463	
Durham University	783	263	520	428	
University of Bath	748	288	460	382	
University of Hull	780	320	460	371	
University of Ulster	720	274	446	353	
University of Surrey	710	284	426	349	
University of the West of England	684	268	416	348	
Swansea University	618	198	420	340	
De Montfort University	761	344	417	336	
Liverpool John Moores University	708	302	406	335	
University of Reading	612	205	407	329	
Birkbeck, University of London	582	223	359	291	
University of Abertay, Dundee	648	281	367	286	
University of St. Andrews	569	210	359	281	
Aston University	595	260	335	266	
University of Wales	845	676	169	151	

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[20] The publication dataset for University of Cambridge, which appears as a separate entity from Cambridge Neuroscience in the benchmarking list, includes those papers that have at least one address from the University of Cambridge in the neuroscience dataset. This results in some overlap between the University of Cambridge and Cambridge Neuroscience.

Figure 2. Average of Relative Citation scores as a function of the volume of publications in the post-2007 period for Cambridge Neuroscience and the ten institutes selected by Cambridge Neuroscience for benchmarking

Figure 3. Map presenting the key bibliometric indicators for Cambridge Neuroscience and the ten institutes selected by Cambridge Neuroscience for benchmarking (post-2007 period)

University of Edinburgh

Volume of publications = **2,977**

Average of Relative Citations (ARC) = **1.45**

Percentage of Highly Cited Publications (HCPs) = **17.0%**

Average of Relative Impact Factors (ARIF) = **1.41**

Share of papers with international collaboration = **47.7%**

Newcastle University

Volume of publications = **2,022**

Average of Relative Citations (ARC) = **1.50**

Percentage of Highly Cited Publications (HCPs) = **17.6%**

Average of Relative Impact Factors (ARIF) = **1.32**

Share of papers with international collaboration = **49.2%**

University of Oxford

Volume of publications = **5,508**

Average of Relative Citations (ARC) = **1.86**

Percentage of Highly Cited Publications (HCPs) = **22.7%**

Average of Relative Impact Factors (ARIF) = **1.42**

Share of papers with international collaboration = **56.3%**

University of Glasgow

Volume of publications = **2,148**

Average of Relative Citations (ARC) = **1.64**

Percentage of Highly Cited Publications (HCPs) = **14.9%**

Average of Relative Impact Factors (ARIF) = **1.32**

Share of papers with international collaboration = **48.5%**

Cambridge Neuroscience

Volume of publications = **6,142**

Average of Relative Citations (ARC) = **2.02**

Percentage of Highly Cited Publications (HCPs) = **24.8%**

Average of Relative Impact Factors (ARIF) = **1.56**

Share of papers with international collaboration = **50.9%**

University College London

Volume of publications = **10,952**

Average of Relative Citations (ARC) = **1.71**

Percentage of Highly Cited Publications (HCPs) = **20.7%**

Average of Relative Impact Factors (ARIF) = **1.40**

Share of papers with international collaboration = **55.7%**

University of Manchester

Volume of publications = **3,245**

Average of Relative Citations (ARC) = **1.43**

Percentage of Highly Cited Publications (HCPs) = **14.9%**

Average of Relative Impact Factors (ARIF) = **1.28**

Share of papers with international collaboration = **49.4%**

Cardiff University

Volume of publications = **2,009**

Average of Relative Citations (ARC) = **1.46**

Percentage of Highly Cited Publications (HCPs) = **14.9%**

Average of Relative Impact Factors (ARIF) = **1.28**

Share of papers with international collaboration = **47.8%**

King's College London

Volume of publications = **6,030**

Average of Relative Citations (ARC) = **1.70**

Percentage of Highly Cited Publications (HCPs) = **19.7%**

Average of Relative Impact Factors (ARIF) = **1.34**

Share of papers with international collaboration = **57.6%**

University of Bristol

Volume of publications = **2,303**

Average of Relative Citations (ARC) = **1.48**

Percentage of Highly Cited Publications (HCPs) = **15.6%**

Average of Relative Impact Factors (ARIF) = **1.31**

Share of papers with international collaboration = **47.2%**

Imperial College London

Volume of publications = **3,551**

Average of Relative Citations (ARC) = **1.69**

Percentage of Highly Cited Publications (HCPs) = **19.3%**

Average of Relative Impact Factors (ARIF) = **1.37**

Share of papers with international collaboration = **55.1%**

11

Cambridge Neuroscience research themes

15. The Cambridge Neuroscience initiative has five associated themes: (i) Developmental Neuroscience, (ii) Cellular and Molecular Neuroscience, (iii) Systems and Computational Neuroscience, (iv) Cognitive and Behavioural Neuroscience, and (v) Clinical and Veterinary Neuroscience. Because these thematic areas came into existence with the formation of Cambridge Neuroscience in 2007, the results in this subsection only focus on the 2008–2014 period.[21]

16. Figure 4 presents the bibliometric indicators of impact by Cambridge Neuroscience theme (i.e. ARC, % HCP and ARIF) for the post-2007 period. All five themes perform substantially better than the world average in terms of the citation impact of their overall portfolio (i.e. the ARC score) and in terms of % HCPs. The Clinical and Veterinary Neuroscience theme performs particularly well on both of these indicators: it has the highest ARC value (2.42) and the second highest % HCP score (26.6%) after the Cellular and Molecular Neuroscience theme (% HCP = 27.4%). All five themes also target their research outputs in journals with above world average citation rates (with ARIF values for targeted journals ranging from 1.46–1.72 across themes).

17. Table 5 presents the yearly trend in the volume of publications for the five research themes over the period 2008–2014.[22] With 2,473 publications, the Cognitive and Behavioural Neuroscience research theme had the highest publication output (40.3%), followed by the Cellular and Molecular Neuroscience (1,743 publications; 28.4%), Clinical and Veterinary Neuroscience (1,541 publications; 25.1%), Systems and Computational Neuroscience (703 publications; 11.4%) and Developmental Neuroscience (567 publications; 9.2%) themes. We do not have information that would enable us to normalise this against the number of researchers per theme.

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[21] As Science-Metrix uses a minimum citation window of three years (i.e. publication year plus the following two years) to compute the ARC and HCP indicators, these indicators are not computed beyond 2011. The ARIF indicator is, however, computed up to 2014.

[22] Please note that the data are incomplete for 2014.

Figure 4. Primary indicators of publication impact (Average of Relative Citations, percentage of Highly Cited Publications and Average of Relative Impact Factors) for the different Cambridge Neuroscience research themes for the post-2007 period
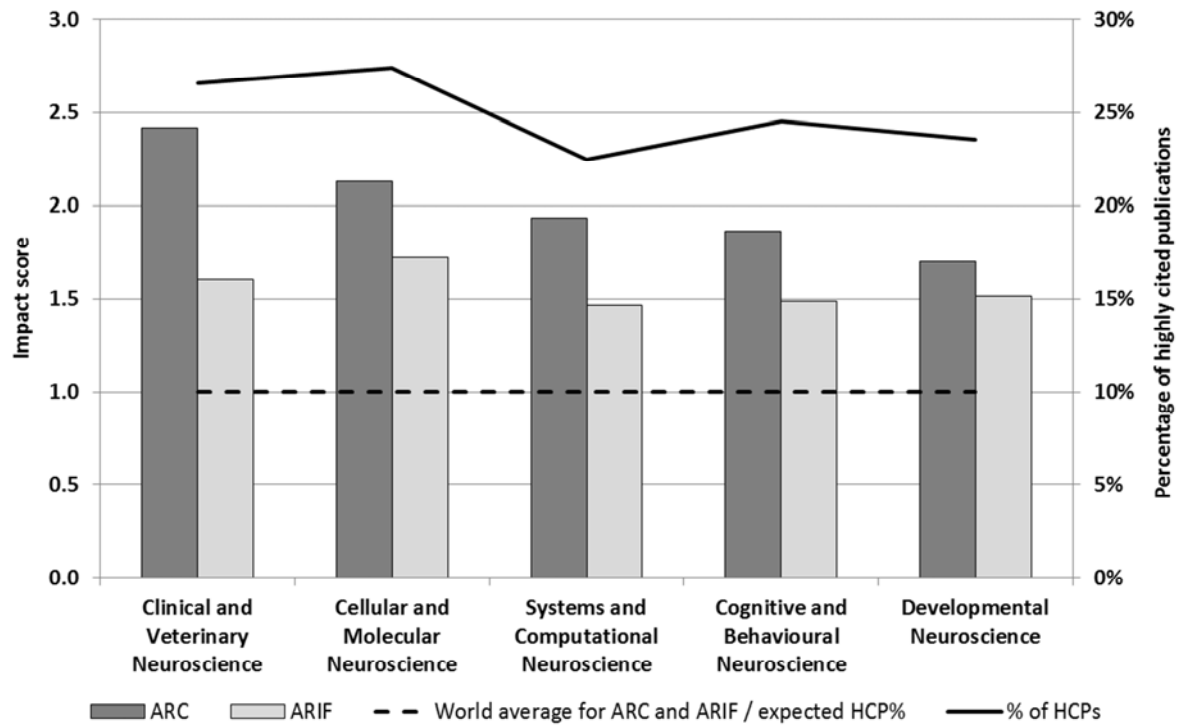
Table 5. Trend in the volume of publications for the five Cambridge Neuroscience research themes (sorted in descending order of the total number of publications)[23]

Research theme	Volume of publications								Proportion of the total number of unique publications (2008-2014)	Yearly trend (2008-2014)
	2008	2009	2010	2011	2012	2013	2014	Total (2008-2014)		
Cognitive and Behavioural Neuroscience	316	380	411	390	456	480	40	2,473	40.3%	
Cellular and Molecular Neuroscience	250	261	316	304	313	286	13	1,743	28.4%	
Clinical and Veterinary Neuroscience	227	249	243	257	235	296	34	1,541	25.1%	
Systems and Computational Neuroscience	105	109	128	105	131	118	7	703	11.4%	
Developmental Neuroscience	66	82	87	99	116	109	8	567	9.2%	

[23] Note that the figures in the percentage column do not add up to 100% because the output share of each theme has been calculated as a fraction of the total number of unique publications produced between 2008 and 2014 (i.e. 6,142).

13

Departments affiliated with Cambridge Neuroscience

18. Most departments affiliated with the network show growth in neuroscience publication outputs between the pre- and post-2007 periods (but we do not have information on how this relates to changes in the size of departments in terms of staff numbers). Clinical Neuroscience, Psychology and Psychiatry have the highest volume of neuroscience publications. The highest growth in outputs between the pre- and post-2007 periods is associated with neuroscience research taking place in some departments that might be considered 'less traditional' for this field of research.[24] However, the departments which are more heavily focused on neuroscience research also show growth in their scientific activity (e.g. the departments of Psychiatry; Psychology; Clinical Neurosciences; and Physiology, Development and Neuroscience).

19. The vast majority of Cambridge departments engaged with neuroscience research (over 90%) perform above the world average in terms of the citation impact of their research portfolio (i.e. ARC > 1); they also have more than the expected number of HCPs. Medical Genetics, Clinical Biochemistry, Public Health and Primary Care, Genetics, and Psychiatry top the list in terms of the citation performance of the overall portfolio in the post-2007 period. In terms of HCPs specifically, the following departments stand out most: Clinical Biochemistry, Medical Genetics, Genetics, Psychology, and Physics. Some of these departments (e.g. those of Physics and Genetics) may have a relatively small part of their portfolio in neuroscience research but, nevertheless, do particularly well in that area.

20. Half of the departments affiliated with Cambridge Neuroscience show higher overall portfolio impact (i.e. in terms of the ARC scores), and 59% show higher % HCP scores in the post-2007 period compared with the pre–2007 period. This indicates continual commitment to excellence and improvement.

Institutes affiliated with Cambridge Neuroscience

21. The vast majority of the institutes affiliated with Cambridge Neuroscience (75%)[25] exhibit a positive growth rate in the number of publication between the pre- and post-2007 periods (but we lack information on how this relates to changes in the size of institutes in terms of staff numbers).

22. Of the 32 institutes for which a portfolio impact score (ARC value) could be calculated,[26] 84% perform better than the world average when their overall portfolio is analysed, and 90% have more than the expected percentage of HCPs. In terms of the overall portfolio impact score, the Cambridge Institute for Medical Research and the Wellcome Trust-Medical Research Council Cambridge Stem Cell Institute stand out in particular, followed by the Behavioural and Clinical Neurosciences Institute, the Institute for Metabolic Science, and the Neurology Unit in the top

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[24] For example, the Biological Anthropology (relatively small absolute number of papers), Surgery, Chemical Engineering and Biotechnology, Physics (relatively small absolute number of papers), and Applied Mathematics and Theoretical Physics departments (relatively small absolute number of papers).

[25] That is, which have been in existence over this time period.

[26] That is, for which the volume of analysable publications was high enough to calculate the ARC indicator.

five. In terms of HCPs, the Institute of Metabolic Science stands out in particular for the post-2007 period, followed closely by the Wellcome Trust-Medical Research Council Cambridge Stem Cell Institute, as well as by the Cambridge Institute for Medical Research, the Behavioural and Clinical Neurosciences Institute and the Autism Research Centre.

23. There is a growth in the citation impact of research by institutes affiliated with Cambridge Neuroscience between the pre- and post-2007 periods (54% show higher ARC scores, and 57% show higher % HCP scores).

Individuals and staff categories

24. When the data are analysed at the individual level, the vast majority of Cambridge Neuroscience researchers produce publications with above world average citation impact.[27] This applies both for citation impacts of their entire neuroscience portfolio (88% perform above world average based on ARC scores in the pre-2007 period and 86% do so in the post-2007 period) (Figure 5) and for their % HCPs (approximately 84% have more publications in the HCP category than would be expected in both the pre- and post-2007 periods) (Figure 6).

25. Although Principal Investigators (PIs) account for the majority of publications (as expected), Research Associates, PhD students, Research Assistants and MPhil students have all been active with publishing activity in the network. The volume of output for each staff category has increased in the post-2007 period, and particularly strikingly so for Research Associates and PhD students (although in absolute terms these two groups have considerably lower numbers of publications). The extent to which this is linked to growth in the absolute number of staff as opposed to increased productivity (outputs/staff) is not known. As expected for a university and a research network of this calibre, the neuroscience portfolio publication impact (i.e. the ARC score) across staff categories is higher than the world average, particularly for the PI group (which has an ARC score that is more than twice that of the world average). Their citation impact has remained relatively consistent over time.

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[27] That is, for whom valid ARC scores could be computed.

Figure 5. Average of Relative Citation scores versus number of publications for individual researchers belonging to Cambridge Neuroscience for the post-2007 period
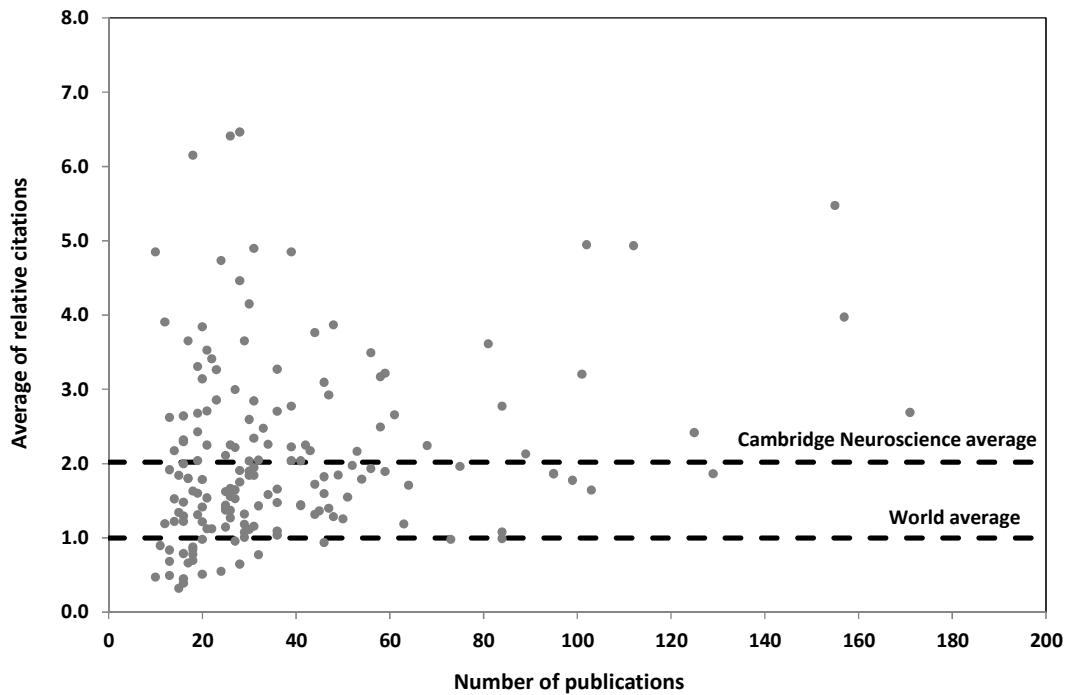
Figure 6. Percentage of Highly Cited Publications versus number of publications for individual researchers belonging to Cambridge Neuroscience for the post-2007 period
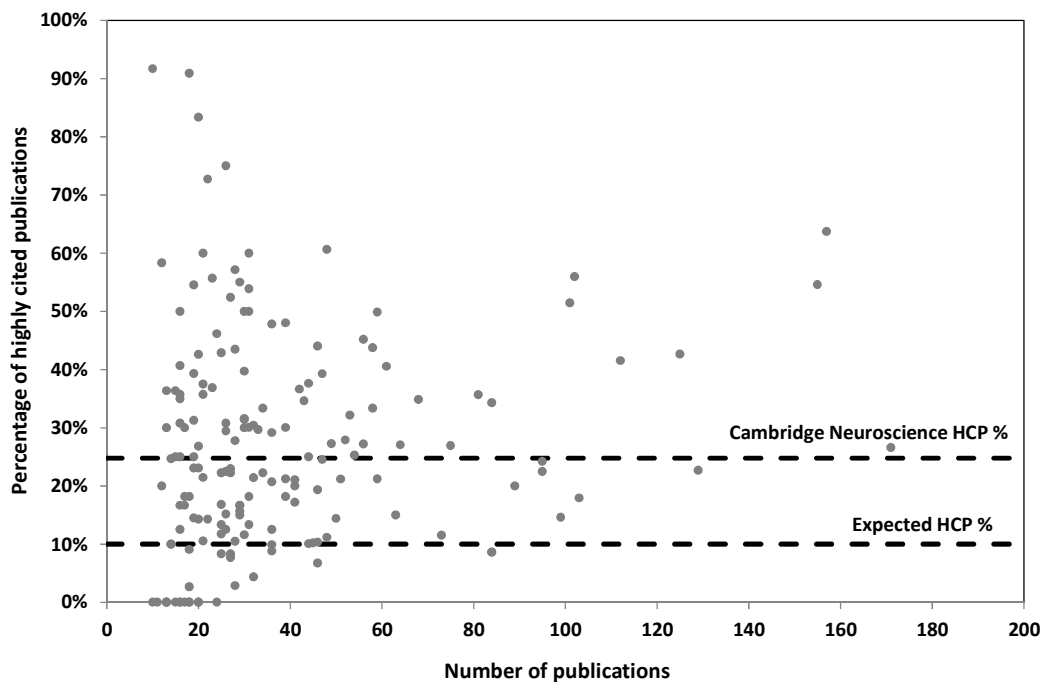
Bibliometric fields within which Cambridge Neuroscience researchers publish

26. Neuroscience research from the Cambridge Neuroscience network is published in journals belonging to a wide variety of bibliometric fields.[28] The majority of papers do better than world averages for a field in terms of citations, both for the ARC and the % HCP indicators. For ARC, this applies to publications in 12 out of 13 fields (92%) with valid relative citation scores in the post-2007 period. Research papers in the bibliometric fields of Clinical Medicine, Social Sciences,[29] Biomedical Research, and Biology score particularly high – appearing in the top five for both ARC and % HCP. Psychology and Cognitive Sciences are also in the top five for ARC, and Public Health and Health Services are in the top five for % HCPs. Within all the bibliometric fields with valid ARIF scores in the post-2007 period, Cambridge Neuroscience targets journals with above world average journal impacts.

Collaboration dynamics

27. Collaboration on publications among researchers currently associated with Cambridge Neuroscience has increased since the network was formed in 2007. In the post-2007 period, nearly half (45%) of the publications associated with Cambridge Neuroscience involved at least one national collaborator, and just over half (51%) involved at least one international collaborator (Table 6). Compared with the pre-2007 period, national collaboration has increased by approximately 4 percentage points, and international collaboration, by about 10 percentage points. Cambridge Neuroscience researchers publish most often with colleagues from the USA, Germany, Australia, the Netherlands and Canada.

28. Approximately 12% of publications involve collaboration between more than one Cambridge Neuroscience theme and between more than one affiliated department of the university. The Clinical and Veterinary Science theme appears to be a particularly collaborative thematic group – appearing in the top three across internal, national and international collaboration statistics.

29. Using the dataset provided by Cambridge Neuroscience and matching the corresponding publication identifiers to the corresponding ID in the WoS database, we were able to create a collaboration network based on co-authorship.[30] In the network graphs presented here, the size of the 'bubbles' is proportional to the number of publications of a researcher, and the width of the edges is proportional to the number of co-publications between researchers. The colour-coding used in the graphs is based on the corresponding research theme or the department for each

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[28] As noted previously, each bibliometrically analysable publication could fall into a particular subject-based WoS journal set, and this could be any of the 177 subfields from Science-Metrix's taxonomy in WoS. Each subfield is itself assigned to one of 22 specific fields.

[29] A relatively low number of publications are assigned to Social Sciences.

[30] Authors were linked together when they shared an article ID which is represented in the edges list. The nodes list is a comprehensive listing of all the researchers whom we could identify, with their corresponding department and research theme, which allowed us to colour code the networks. Articles were separated in three periods, representing the periods before and after the implementation of Cambridge Neuroscience and a third period that allows us to observe links between researchers regardless of their affiliation to Cambridge Neurosciences. All actors who had no collaborations with members of Cambridge Neurosciences (i.e. an unweighted degree of 0) were removed to prevent visual cluttering. The networks were produced using the software Gephi and the OpenOrd algorithm.

researcher. The collaboration network of Cambridge Neuroscience researchers coded by research theme for the post-2007 period is presented in Figure 7. A high degree of collaboration can be noted from the network, echoing the results in Table 6. The central players in the network are those researchers with large publication outputs. Acting as potential 'knowledge brokers' between the various themes, these individuals frequently collaborate – to varying degrees – with numerous researchers from other research themes. As indicated by the thickness of the lines connecting the respective nodes, some researchers from different themes have particularly strong co-publication relationships.

30. Figure 8 illustrates the collaboration networks coded by departmental affiliation of each Cambridge Neuroscience researcher for the pre- and post-2007 periods. As was the case with the thematic level of analysis, over both periods there appears to be a high degree of collaboration among researchers across departments. However, in the pre-2007 period, there are clear clusters centred on the researchers with the largest publication outputs. Although the actively publishing researchers still stand out in the post-2007 period, when compared with the pre–2007 network, the scale of collaboration among individuals and departments appears to be greater.[31] Although requiring further analysis, this may indicate that Cambridge Neuroscience is helping enable cross-departmental collaborations among researchers (given its goal and range of networking, collaboration and knowledge-exchange-focused activities).

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[31] The average weighted degree of centrality (i.e. the number of immediate contacts a node has in the network) is higher in the post-2007 period (41.3) compared with the pre–2007 period (31.1). More detailed analysis of the network graphs was outside the scope of this study.

Table 6. Internal, national and international collaboration trends of Cambridge Neuroscience as a whole[32]

| Type of collaboration	Number of collaborative papers			% of collaborative papers			Growth between pre-2007 and post-2007 periods (percentage points)	
	2003-2014	Pre-2007	Post-2007	2003-2014	Pre-2007	Post-2007		
Internal collaboration: publications involving at least two Cambridge Neuroscience researchers	2,313	728	1,585	23.7%	20.1%	25.8%	5.7	⬆
Internal collaboration: publications involving at least two Cambridge Neuroscience themes			752			12.2%		
Internal collaboration: publications involving at least two University of Cambridge departments	1,120	385	735	11.5%	10.7%	12.0%	1.3	⬆
National collaboration: publications involving at least one other organisation from among the top publishing UK organisations in neuroscience	4,294	1,509	2,785	44.0%	41.8%	45.3%	3.6	⬆
International collaboration: publications involving at least one other country	4,629	1,501	3,128	47.5%	41.5%	50.9%	9.4	⬆

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[32] Because the research themes only came into existence with the formation of Cambridge Neuroscience in 2007, the collaboration data for the research themes focus only on the post-2007 period.

Figure 7. Collaboration network of Cambridge Neuroscience researchers coded by research theme for the post-2007 period
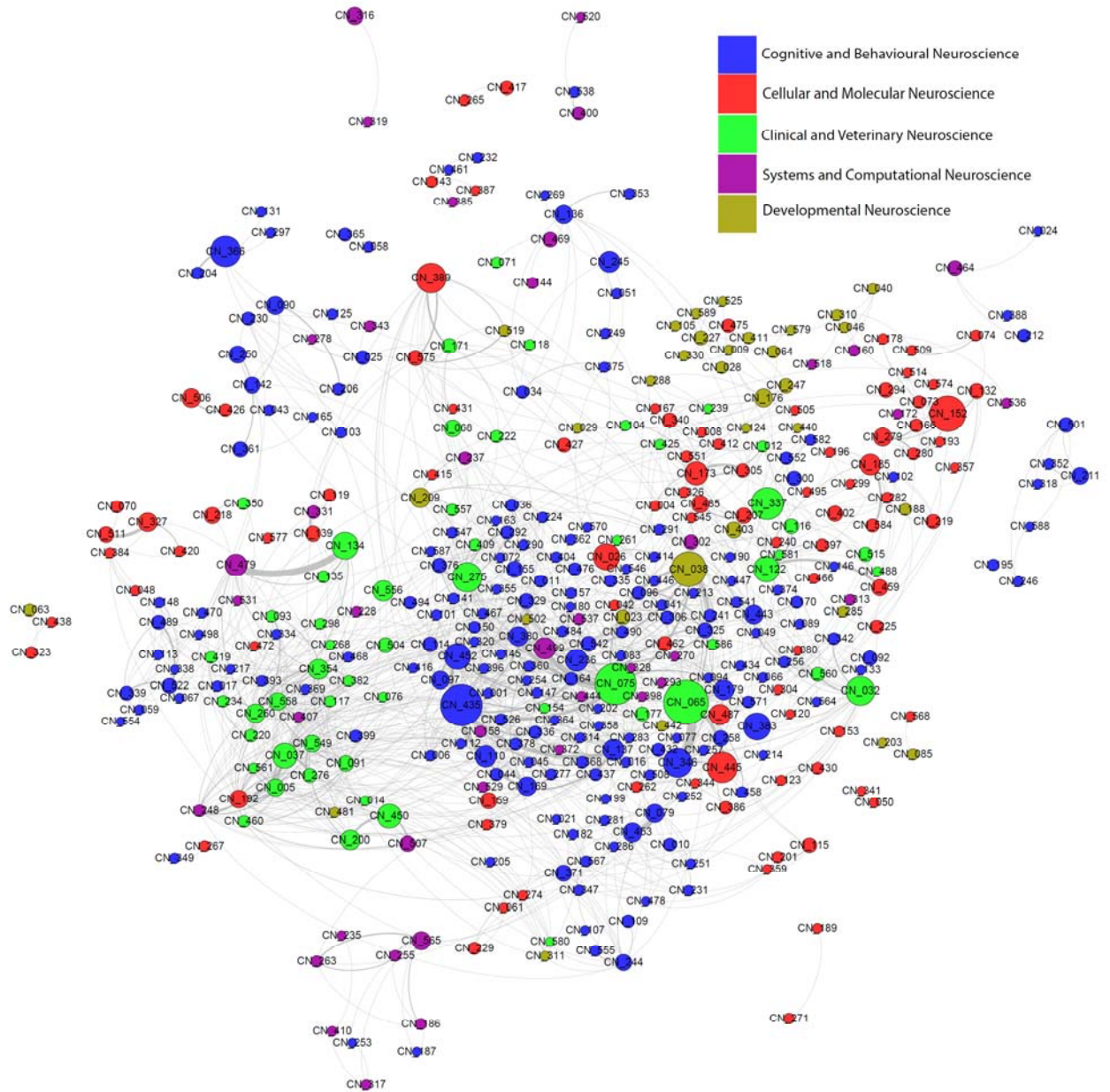
Figure 8. Collaboration network of Cambridge Neuroscience researchers coded by departmental affiliation for the pre-2007 (left frame) and post-2007 (right frame) periods
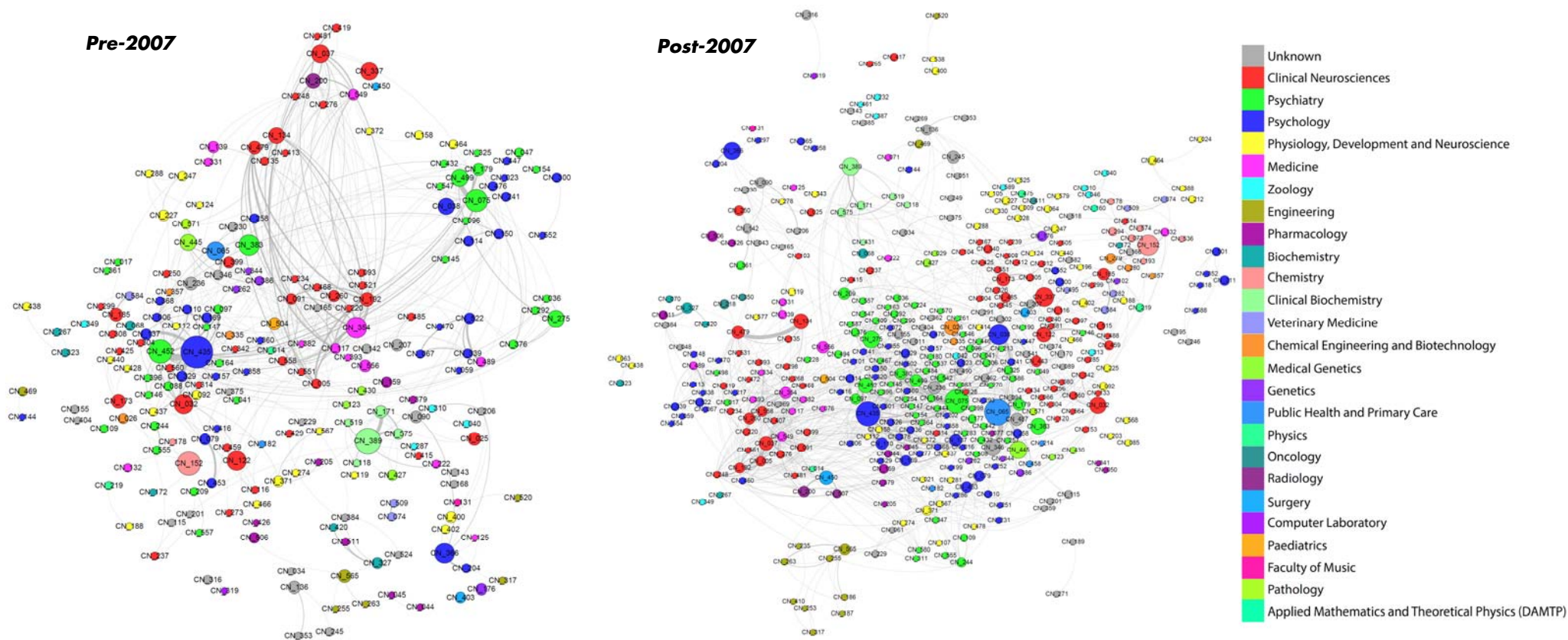
Caveats

31. There are a number of caveats and potential limitations of bibliometric analysis that should be taken into account when interpreting the findings.[33] However, when used responsibly, bibliometrics also mitigates some of the limitations of more traditional research assessment approaches, such as peer review. We summarise some of the key caveats below:

    i. Reliability of bibliometric data can be affected by the bibliometric database coverage. Those entities that do not publish in journals found within the Web of Science cannot be analysed.

    ii. The bibliometric indicators show academic impact and are used as a proxy for quality. Estimates of quality based on publications and citations alone can be misleading because work may be cited for a variety of reasons, not all of which may reflect quality.

    iii. Attribution continues to be a challenging issue because it is not always easy to disentangle the contribution of different authors (or institutions) to a particular research paper.[34] In the context of multi-authored publications (in which co-publications could serve as a proxy for collaboration), the degree of contribution of the various authors, and consequently the contributions of the affiliated institutions, to the publication is not always clear.

    iv. The analysis is based on past outputs and cannot reliably measure future potential.

    v. The accuracy of input data affects the reliability of bibliometric analysis. For example, if applicants only submit their very best publications, rather than all potentially analysable publications, this can skew their results in the bibliometric 'quality' analysis (based on the ARC indicator value). As another example, if inaccurate publication details are provided (e.g. wrong Pubmed or Web of Science identification codes), it can be difficult to ensure a match and identify the publication in a bibliometric database.

    vi. The bibliometric analysis looks at citations from the academic literature (typically focussing on journal articles and reviews) and does not include citations from non-indexed literature (e.g. conference proceedings) and other sources, such as some clinical guidelines.

    vii. Where possible, we also conducted a pre- and post-2007 analysis of bibliometric trends, to provide an indication of whether any differences can be observed before and after the formation of the Cambridge Neuroscience initiative. Whereas any observed differences cannot be causally attributed to the formation of Cambridge Neuroscience from these data alone, they may present a useful foundation for further analyses of causation and attribution and for qualitative investigations.

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[33] See, for example: (i) Ismail, S., E. Nason, S. Marjanovic & J. Grant. 2009. *Bibliometrics as a Tool for Supporting Prospective R&D Decision-making in the Health Sciences*. Santa Monica, Calif.: RAND Corporation. TR-685-DH; (ii) Moed, H.F. 2005. *Citation Analysis in Research Evaluation*. Dordrecht (Netherlands): Springer.

[34] In this study, the number of publications was analysed using full-paper counting, in which each paper was counted once for all the entities listed in the address fields of the publication.

viii.   It is important to note that in the benchmarking exercise, University of Cambridge appears as a separate entity from Cambridge Neuroscience, within the list of top 50 UK organisations publishing neuroscience research. The publication dataset for University of Cambridge includes those papers that have at least one address from the University of Cambridge in the neuroscience dataset. This results in some overlap between the publication datasets under University of Cambridge and Cambridge Neuroscience units of analysis. The University of Cambridge neuroscience publication dataset includes some University of Cambridge publications that are co-authored with researchers affiliated with Cambridge Neuroscience.[35] It also includes some publications which were not submitted by Cambridge Neuroscience (in the source publication dataset) for analysis to the RAND Europe-Science Metrix team, but which could have been eligible for analysis. The impact on the overall findings of including these University of Cambridge publications within the Cambridge Neuroscience publication dataset could not be assessed within the scope of this study. This is discussed in more detail under point 36.

ix.   Finally, the publication list provided to the RAND Europe-Science Metrix team did not prohibit researchers affiliated with Cambridge Neuroscience from submitting publications dating back to 2003, even if at the time some individuals may not have been affiliated with the university. This also could have impacted on the bibliometric results, and if so, the extent of the impact is not known. This would not, however, affect assessments of the 'quality' of people that Cambridge Neuroscience *currently has.*

In reflection

32. This bibliometric analysis provides an overview of the citation impact of neuroscience research at the University of Cambridge and, specifically, research by individuals, departments, institutes and themes associated with the Cambridge Neuroscience Strategic Research Initiative. Citation impact is used a proxy for the quality of research and researchers; the various results need to be interpreted within that context.

33. Our findings suggest that research performance has continuously been high, and substantially above world averages. The benchmarking results clearly indicate that Cambridge Neuroscience has reinforced its position as one of the leading institutions in the UK working in the area of neuroscience.

34. It is likely, although not certain, that Cambridge Neuroscience is adding value to sustaining research excellence through the range of activities it supports. While there is no significant difference in the bibliometric indicators of impact before and after the formation of Cambridge Neuroscience in late 2007 overall,[36] the results of the analysis do indicate that neuroscience research at the University of Cambridge has sustained high academic impact over time (i.e. it has

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[35] Overall, 4,515 publications between 2003 and 2014 are assigned to both Cambridge Neuroscience and the University of Cambridge.

[36] A more granular analysis (e.g. at the theme, department and institute level) does show some differences over time.

always been represented by a relatively 'high performing' group of researchers). As discussed in the report, there are also some examples of departments and institutes with notable changes in impact over time. Furthermore, the level of collaboration between researchers affiliated to the network and other national and international collaborators has increased.

35. However, analysis of the initiative's specific contribution to scientific impact would require further qualitative investigations. We recommend that interviews and/or surveys with network members, potentially coupled with a 'futures thinking' (scenario) workshop, could help interpret the impact of the network and of the various activities under its domain on individuals, departments, institutes and the wider university. Such analysis could also help elucidate the reasons behind particularly striking improvements or decreases in citation performance or publication volumes for specific units of analysis. Or it could help investigate and identify the pockets of excellence in less traditional neuroscience units,[37] and as such help inform future network activities and strategic support. In terms of further quantitative investigations, if the yearly changes in staff numbers at, for example, the theme or departmental level were known, then the 'growth' of output and impact could be ascertained with a greater degree of confidence.

36. The analysis is based on publication data provided by Cambridge Neuroscience to the RAND Europe-Science Metrix team. As previously mentioned, there are a number of caveats to bear in mind when interpreting the data. Some of these apply to bibliometric analysis more widely and others are specific to the current investigation. In the context of the latter, it is important to note that our analysis revealed that not all publications associated with Cambridge Neuroscience (and thus potentially eligible for analysis) were submitted by Cambridge Neuroscience in the source publication file. In principle, this could affect the findings, as the accuracy of bibliometric analysis depends on the accuracy of input data. It was outside the scope of this work to investigate the nature of any such impact further. However, Cambridge Neuroscience carried out a rapid scoping exercise to determine the main reasons for these unsubmitted publications.[38] The key reasons communicated by Cambridge Neuroscience included: (i) researchers currently affiliated to Cambridge Neuroscience who have missed some of their publications; (ii) people who have left the University of Cambridge (for other universities) or who have retired and who are no longer active in this field; (iii) people whose primary subject is not neuroscience so they have not felt it necessary to join the neuroscience network but have 1–2 publications in that area, or those who have elected not to join Cambridge Neuroscience; (iv) those who have collaborated with others outside Cambridge in the past and have contributed to papers (not as a significant author) and who have now left Cambridge; and (v) those whose main subject might not be neuroscience but

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[37] For example, in Physics or in niche areas.

[38] We e-mailed a publication dataset (of 3,088 publications) to the client that generally included 'University of Cambridge' neuroscience publications that were not matched to any publications listed in the original pool of publications submitted by Cambridge Neuroscience to the RAND Europe-Science Metrix team. It must be noted, however, that a very small minority of publications that were supplied as part of the source Cambridge Neuroscience list are likely to be present in the 'University of Cambridge' list as well (c1–2%). Science-Metrix has run tests and is confident that this would not impact on the overall findings. It is, however, an inevitable caveat of the methodology. The reason for this is that any bibliometrics matching process is not 100% sensitive and specific. Science Metrix' algorithms are 98% precise, and they are the state of the art, so we are confident that using them ensures reliable and robust findings.

more social/behavioural/cancer/cardiovascular, etc. (e.g. neuroscience contributions to an oncology paper).

37. Although tentative, these reasons suggest that a substantial number of publications which were not submitted were not eligible for analysis anyway (i.e. people who left Cambridge or did not have an affiliation with the Cambridge Neuroscience initiative). However, the impact of those publications which would be eligible for analysis would need to be investigated further to make any conclusive assessments of impact on overall scores. A modified approach to sourcing input data could help mitigate these challenges in future analyses of this nature. For example, the RAND Europe-Science Metrix team could do an initial identification based on key information about individuals and send this for validation by the university and relevant individuals.