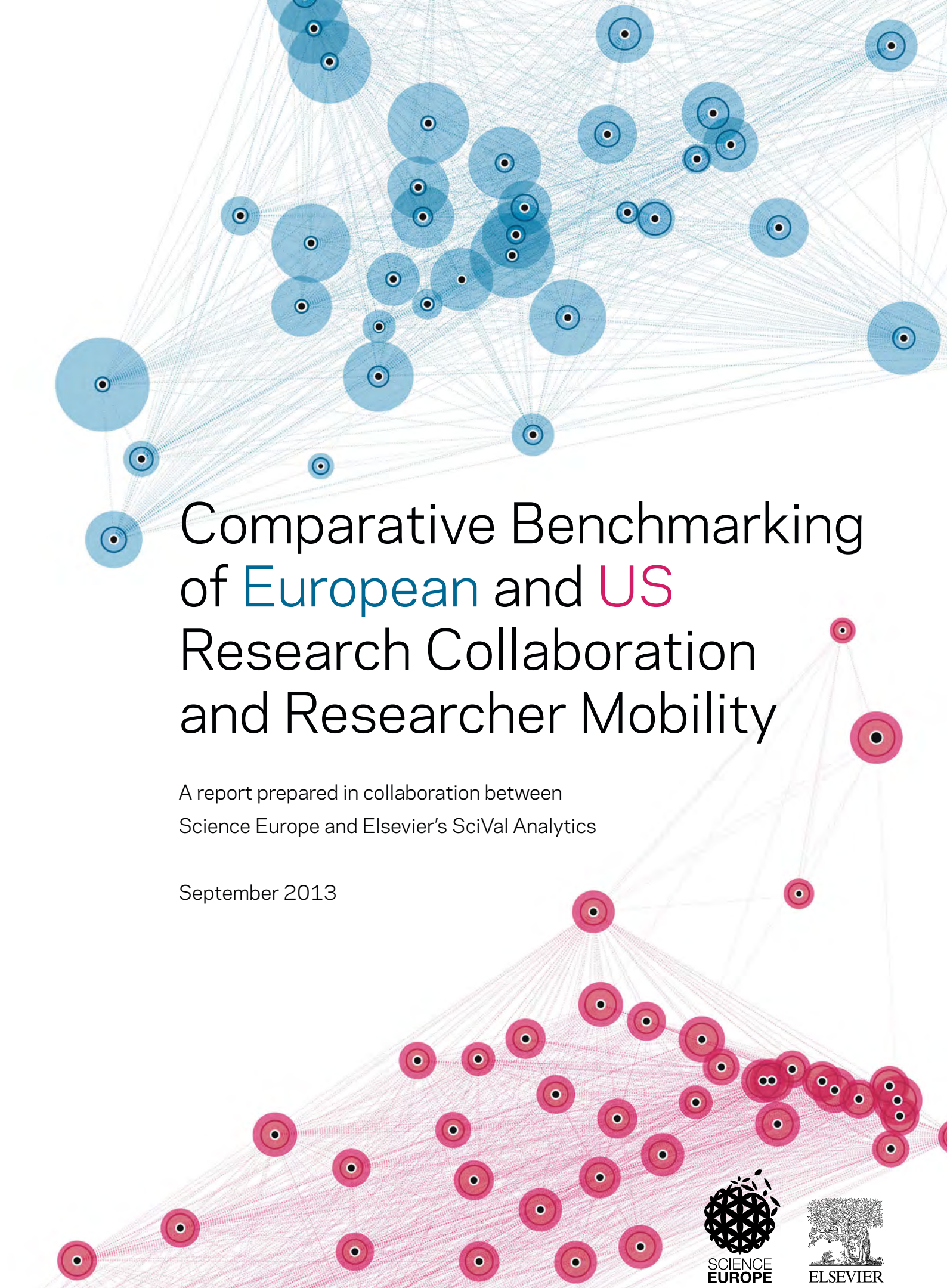


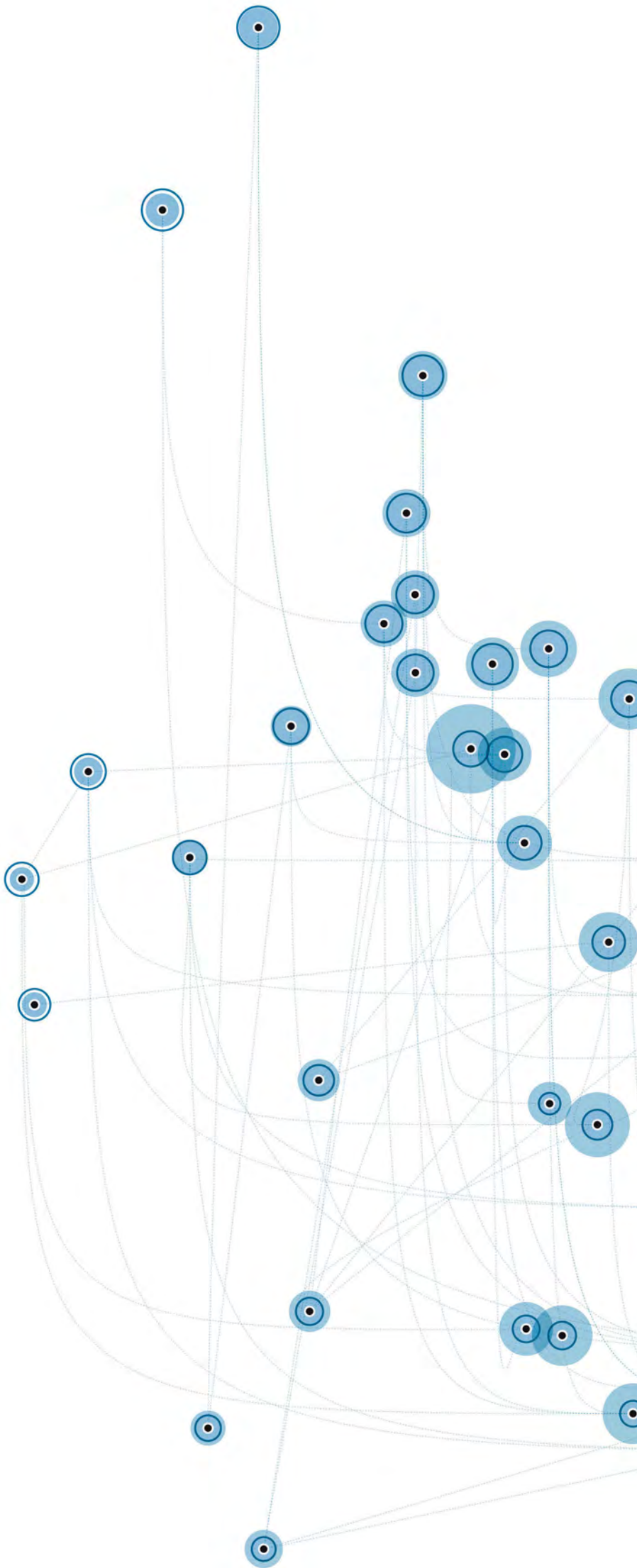
Comparative Benchmarking of European and US Research Collaboration and Researcher Mobility

A report prepared in collaboration between
Science Europe and Elsevier's SciVal Analytics

September 2013

SCIENCE EUROPE

ELSEVIER



CONTENTS

EXECUTIVE SUMMARY

Comparative Benchmarking of European and US Research Collaboration and Researcher Mobility

This report focuses on the extent to which research collaboration and researcher mobility patterns differ between Europe and the US, based on analysis of the Scopus publication database [1]. This comparison is made by exploring both the extent to which academics collaborate on research papers and the amount of researcher mobility within Europe or within the US and beyond, based on author affiliations. In particular, we are interested in whether there is as much collaboration between countries in Europe as there is between states in the US. The first study of its type, it serves as a benchmark against which we can compare such collaboration in the future.

In terms of absolute volume of research outputs (articles, reviews and conference papers indexed in Scopus), Europe collectively produces more than the US alone, and this gap is growing. In 2011, Europe produced 33.4% of the world's research outputs, while the US accounted for 23.4%.

We divide papers into five categories: single author; those involving collaboration between authors in a single institution; collaboration within a single country (Europe) or state (US); collaboration between countries (Europe) or states (US); and collaborations involving at least one researcher from outside either Europe or the US. We find that inter-country collaboration in Europe accounts for 13% of papers in 2011, while inter-state collaboration in the US accounts for 16% of papers. Also, this small difference is diminishing – the percentage rose by more than two points between 2003 and 2011 in Europe, while the percentage in the US fell slightly over that period. This suggests that the national- and European-level mechanisms to encourage cross-country collaboration in Europe seem to be working. As we might expect, though, there is considerable variation by discipline.

Researchers in the US are more likely to collaborate with researchers from outside the US than researchers in Europe are likely to collaborate with researchers outside Europe. This is important as 'outside region' collaboration has the greatest citation benefit – in fact the additional benefit of collaborating outside region is proportionally greater for European researchers than for US researchers.

When looking at collaboration for European countries and US states more closely, we see evidence that both European and US researchers are collaborating with researchers in some of the smaller research nations (such as Albania and Macedonia) even where this does not improve the citation impacts for those countries. In fact, both the collaboration network for countries in Europe and the network for states in the US are almost exhaustively inclusive, in the sense that in 2011 every state or country collaborates with every other state or country within the two regions.

While the collaboration patterns between European countries are broadly similar to those between US states, it is clear that researcher migration between different countries within Europe is considerably less frequent than migration between states in the US. One might argue that the attitude among funding agencies to allowing the grants they have awarded to move across borders may be part of the explanation for this. However, factors that are more likely to be influential would include the differences in culture, language, administrative systems, benefits, pensions and other support systems, which continue to vary considerably across Europe. In the US, there is greater comparability of employment law and compensation packages between states.

When looking at migration patterns for Europe and the US more closely, we see that European researchers are more immobile in the comparatively 'weaker' research nations, while US researchers are more immobile in the 'stronger' research states (although there is variation around this).

KEY FINDINGS

INTER-COUNTRY / INTER-STATE

Similar levels for Europe (13%) and US (16%) and the difference is diminishing

COLLABORATION OUTSIDE REGION

Results in highest impact for both the US and Europe, but effect is larger for Europe

RESEARCHER MIGRATION

Less movement between European countries than between US states

SEDENTARY RESEARCHERS

Europe: high impact country = high mobility, US: high impact state = low mobility

[1] The Scopus database, being the largest abstract and citation database of peer reviewed research literature in the world, represents well the geographical, language and disciplinary distributions of publications observed globally. However, even though Scopus is rapidly increasing its coverage in Arts and Humanities, the fact that other sources such as books play such an important role in this subject area means that the results may only partially apply to this discipline.

This report was prepared in collaboration between Science Europe and Elsevier's SciVal Analytics, September 2013.

INTRODUCTION

This report is the result of collaboration between Elsevier and Science Europe, with a view to providing an analysis of European and US research collaboration and researcher mobility patterns, as reflected in the Scopus online database. Although the countries of Europe are often grouped together, there is much variance between them. An important issue for European research is the amount of academic collaboration taking place within Europe. This report explores both the extent to which academics collaborate on research papers and the amount of researcher mobility within Europe and beyond, based on author affiliations.

Research collaboration and researcher mobility have been acknowledged as complementary processes. In the former, researchers may collaborate across great physical distances, using the latest developments in telecommunications to work together, such that they may never even meet in person; in the latter, researchers may relocate to work alongside new or existing colleagues, sometimes a distance of just a few miles and others to the other side of the world. Owing to the dynamic and mobile nature of modern research, these two processes are difficult to disentangle, but it is nevertheless possible to measure them using comprehensive databases of published outputs.

Europe and the United States (US) collectively represent some of the greatest scientific nations in the world. Europe is home to 1.64 million researchers, while the US number approaches 1.47 million [2]. In terms of absolute volume of research outputs (articles, reviews and conference papers indexed in Scopus), Europe collectively produces more than the US alone (Fig. 1), which stands as the world's most productive research nation. Indeed, Europe's productivity continues to increase while the US's growth has slowed somewhat in recent years. In 2011, Europe produced 33.4% of the world's research outputs, while the US accounted for 23.4%.

A common concern voiced by various groups in Europe is that there is less collaboration among researchers across Europe than might be found between researchers elsewhere – the US is often held up as an example where researchers are able to collaborate more freely than in Europe. In particular, there are concerns that researchers may be less mobile between, and may be less likely to collaborate with partners in, the different countries of Europe compared, for example, with researchers in the different states within the US. Of course, there are various cultural, linguistic and legal reasons why this would be expected to be the case [3], but to date no comparative work has explored the extent to which research collaboration and researcher mobility actually differ between Europe and the US. This report therefore serves as a benchmark which makes such comparisons. The following pages provide more detail on the approaches and definitions used in this exploratory analysis.

The study addresses the following questions:

1. *What is the frequency of research collaboration between countries within Europe and how is this changing? How does this compare with research collaboration between states within the US?*

2. *Do the collaborative patterns of European authors with non-European authors (i.e. those in the rest of the world) differ from those of US authors with non-US authors?*

3. *Do collaborative research outputs have greater citation impact than the non-collaborative outputs for each country within Europe or state within the US?*

4. *Do European researchers' patterns of mobility between European countries (and the rest of the world) differ from US researchers' patterns of mobility between US states (and the rest of the world)?*

[2] Estimates based on OECD and UNESCO data for FTE researchers in 2009, the most complete data currently available.

[3] Some of these potential barriers have been explored in Fraunhofer ISI/Idea Consult/SPRU (2009) The Impact of Collaboration on Europe's Scientific and Technological Performance, pp 145-157.

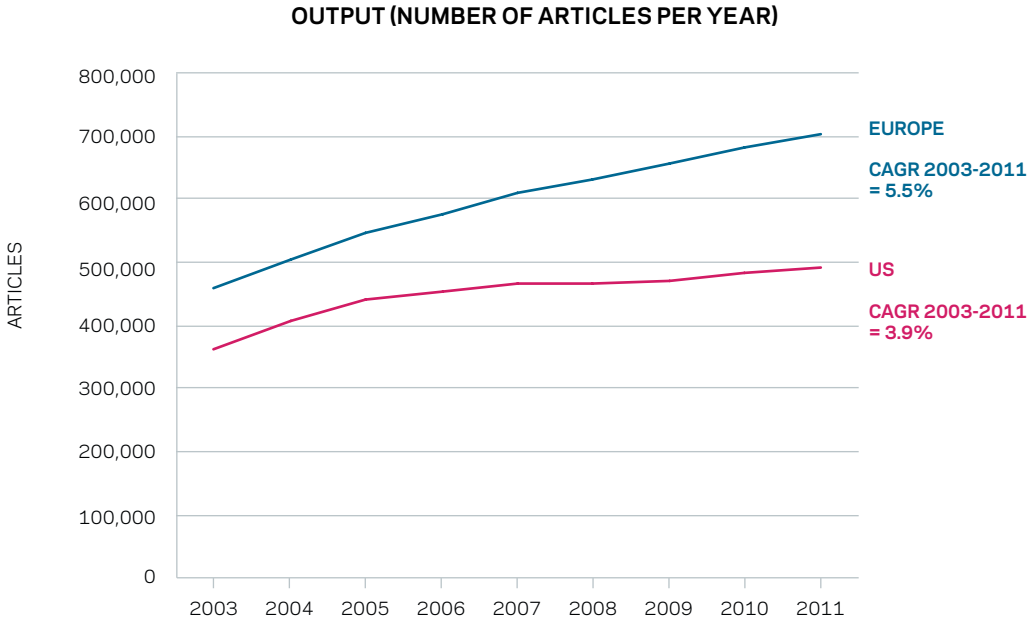


Figure 1 — *European and US output per year, 2003-11, with compound annual growth rate (CAGR).*

Outputs included are articles, reviews and conference papers indexed in sources covered by Scopus, primarily journals, conference proceedings, book series, and trade publications.

APPROACH AND DEFINITIONS

For the purposes of this comparative study of collaboration and researcher mobility between Europe and the US, we consider the **countries of Europe** to be analogous to the **states of the US**; for the sake of clarity, we therefore refer to Europe and the US as **regions** throughout this report. **Research collaboration** is inferred from the pattern of co-authorship of research outputs indexed in Scopus, while **researcher mobility** is determined from author institution affiliation records derived from these outputs.

Defining Europe

For the purposes of this report, Europe has been defined as consisting of the 41 countries with direct eligibility for Seventh Framework Programme (FP7) funding, including all 27 current European Union (EU) member states and 14 associated countries (i.e. those with science and technology cooperation agreements that involved contributing to the framework programme budget). These include all 27 countries from which there are Science Europe member organisations.

Countries:
Albania, Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Faroe Islands, Finland, France, FYR Macedonia, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Moldova, Montenegro, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia (Slovak Republic), Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

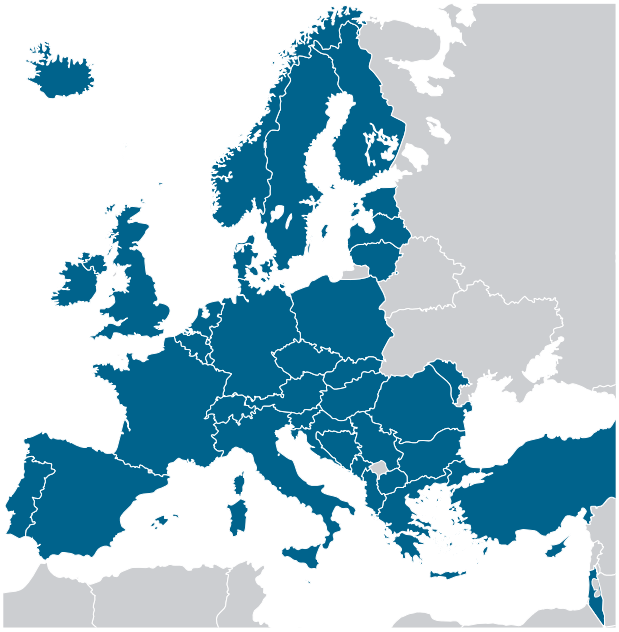


Figure 2 — *Europe defined as consisting of the 41 countries with direct eligibility for Seventh Framework Programme (FP7) funding.*

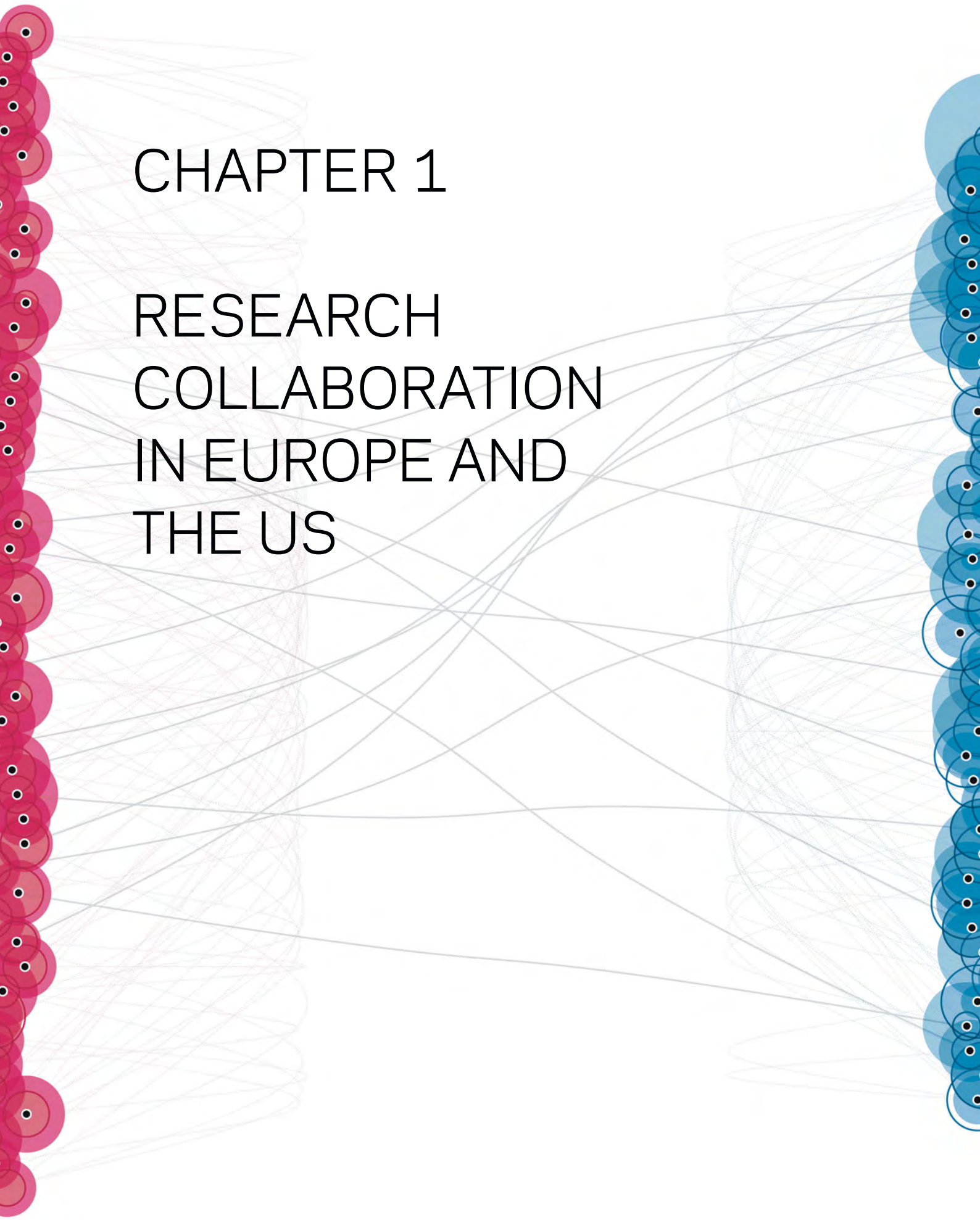
See also Appendix A for a full list of all 41 countries.

TERMINOLOGY

EUROPE		US	
Research collaboration			
Single author	Single-authored research outputs where author is affiliated with an institution in a European country	**Single author**	Single-authored research outputs where author is affiliated with an institution in a US state
Single institution collaboration	Multi-authored research outputs, where all authors are affiliated with the same institution in a European country	**Single institution** collaboration	Multi-authored research outputs, where all authors are affiliated with the same institution in a US state
Intra-country collaboration	Multi-authored research outputs, where authors are affiliated with more than one institution within the same European country	**Intra-state** collaboration	Multi-authored research outputs, where authors are affiliated with more than one institution within the same US state
Inter-country collaboration	Multi-authored research outputs, where authors are affiliated with institutions in more than one European country but all authors are based within Europe	**Inter-state** collaboration	Multi-authored research outputs, where authors are affiliated with institutions in more than one US state but all authors are based within the US
Collaboration **outside region**	Multi-authored research outputs, where authors are affiliated with institutions within one or more European countries, but at least one author is from an institution outside the European region	Collaboration **outside region**	Multi-authored research outputs, where authors are affiliated with institutions within one or more US states, but at least one author is from an institution outside the US region
Researcher mobility			
Sedentary researcher	Researchers with an active author profile whose research outputs list institution affiliation(s) only within a single European country	**Sedentary** researcher	Researchers with an active author profile whose research outputs list institution affiliation(s) only within a single US state
Inter-country mobility	Researchers with an active author profile whose different research outputs list institution affiliation(s) within more than one European country	**Inter-state** mobility	Researchers with an active author profile whose different research outputs list institution affiliation(s) within more than one US state
Mobility **outside region**	Researchers with an active author profile whose different research outputs list institution affiliation(s) within Europe, and in a different country outside of Europe	Mobility **outside region**	Researchers with an active author profile whose different research outputs list institution affiliation(s) within the US, and in a different country outside of the US

CHAPTER 1

RESEARCH COLLABORATION IN EUROPE AND THE US



INTRODUCTION

In this chapter, the following questions surrounding research collaboration in Europe and the US are addressed:

1. What is the frequency of research collaboration between countries within Europe and how is this changing? How does this compare with research collaboration between states within the US?

2. Do the collaborative patterns of European authors with non-European authors (i.e. those in the rest of the world) differ from those of US authors with non-US authors?

3. Do collaborative research outputs have greater citation impact than the non-collaborative outputs for each country within Europe or state within the US?

1.1 RESEARCH COLLABORATION PATTERNS IN EUROPE AND THE US

In 2011, the most recent year included in this analysis, most of the research outputs produced by Europe and the US represent collaborations, defined as co-authorship between two or more researchers. Indeed, in Europe just 12% of outputs have a sole author listed in the by-line, while the same figure is 13% for the US (Fig. 3). The regions show very similar proportions of outputs representing collaboration within a single institution (31% for Europe and 29% for the US). Together these two types of output, which may be considered to reflect institution-focused research outputs, sum to around 42.5% for both Europe and the US.

Moving beyond single institution research, we find that European researchers are more likely to collaborate with researchers at institutions within the same European country (i.e. intra-country collaboration) at 20% than the equivalent collaboration within US states (i.e. intra-state collaboration) at only 10%. Conversely, and of particular interest in this study, collaboration between researchers in different countries within Europe (i.e. inter-country collaboration) at 13% was more similar to the level of collaboration between states within the US (i.e. inter-state collaboration) at 16%.

Finally, US researchers are more likely to collaborate with researchers outside their own region (30%) compared to European researchers (23%). While the pool of available collaboration partners outside of Europe for a European researcher is smaller than the pool available outside the US for a US researcher (because there are more researchers in Europe than in the US), the difference is fairly small and would not explain these percentage differences.

In recent years there has been a global shift in the tendency for researchers to form collaborations that result in co-authored research outputs, with collaboration rates between countries globally rising from 14% in 2003 to 17% in 2011. In both Europe and the US there is a general tendency for inter-institutional collaboration to increase at the expense of single author and single institution publications (Fig. 4). While intra-country collaboration within Europe and intra-state collaboration within the US are growing very slowly, it is the outside region collaboration type that is growing most markedly in both cases. Also, although the inter-state US collaboration is slightly higher than the inter-country European collaborations, this gap is slowly closing over time

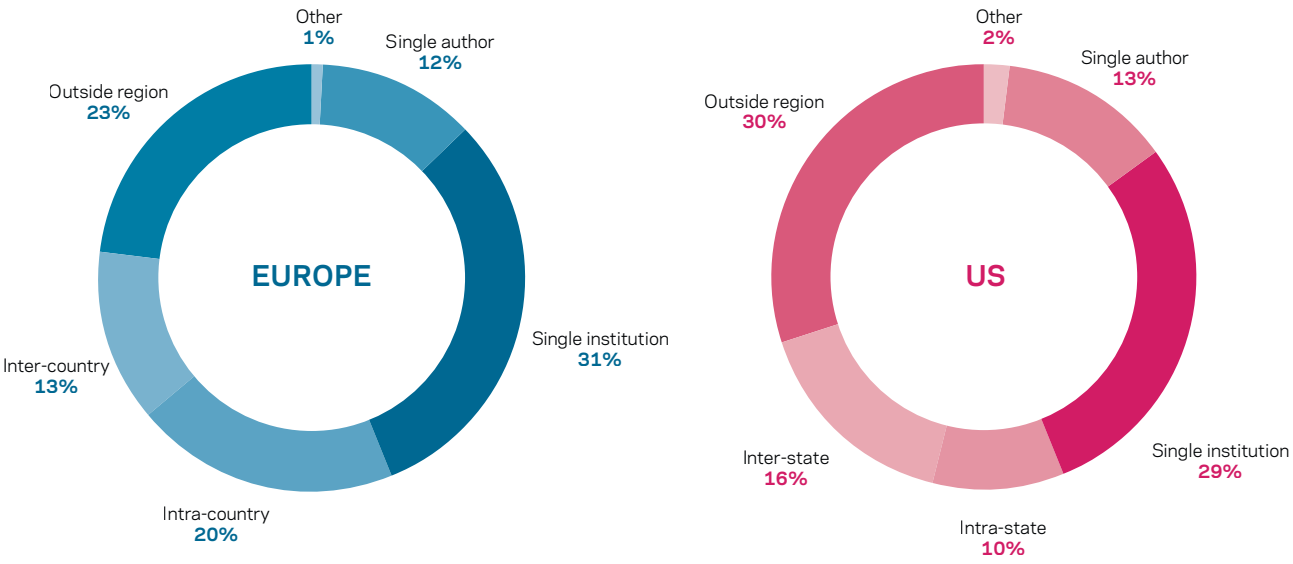


Figure 3 — *European and US research collaboration patterns, 2011.*

Outputs included are articles, reviews and conference papers indexed in sources covered by Scopus, primarily journals, conference proceedings, book series, and trade publications. Collaboration is inferred by the pattern of co-authorship as described in the Approach and Definitions section on page 4; the "other" category consists of articles with two or more affiliations, but owing to a lack of country information the document cannot be accurately classified by collaboration pattern.

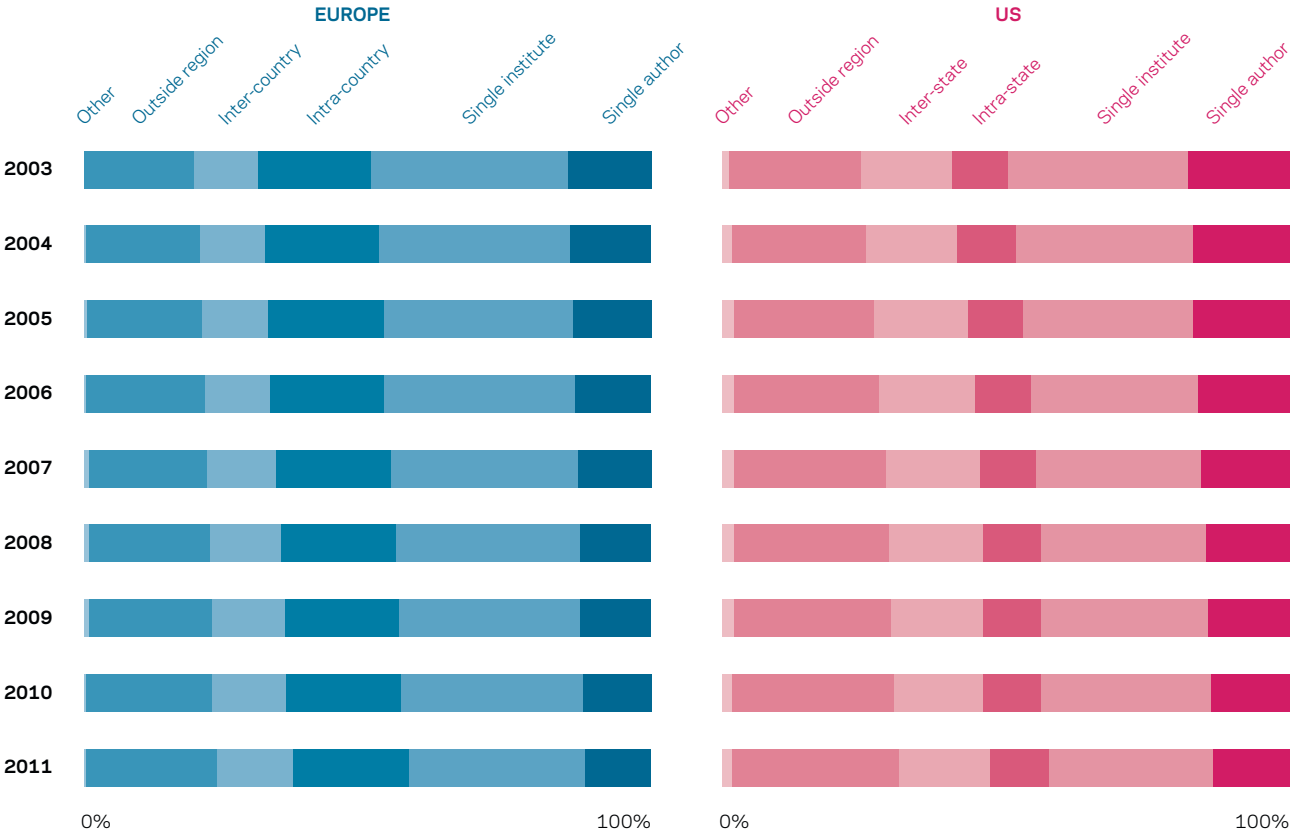


Figure 4 — *European and US research collaboration pattern trends, 2003–11.*

Outputs included are articles, reviews and conference papers indexed in sources covered by Scopus, primarily journals, conference proceedings, book series, and trade publications. Collaboration is inferred by the pattern of co-authorship as described in the Approach and Definitions section on page 4; the "other" category consists of articles with two or more affiliations, but owing to a lack of country information the document cannot be accurately classified by collaboration pattern.

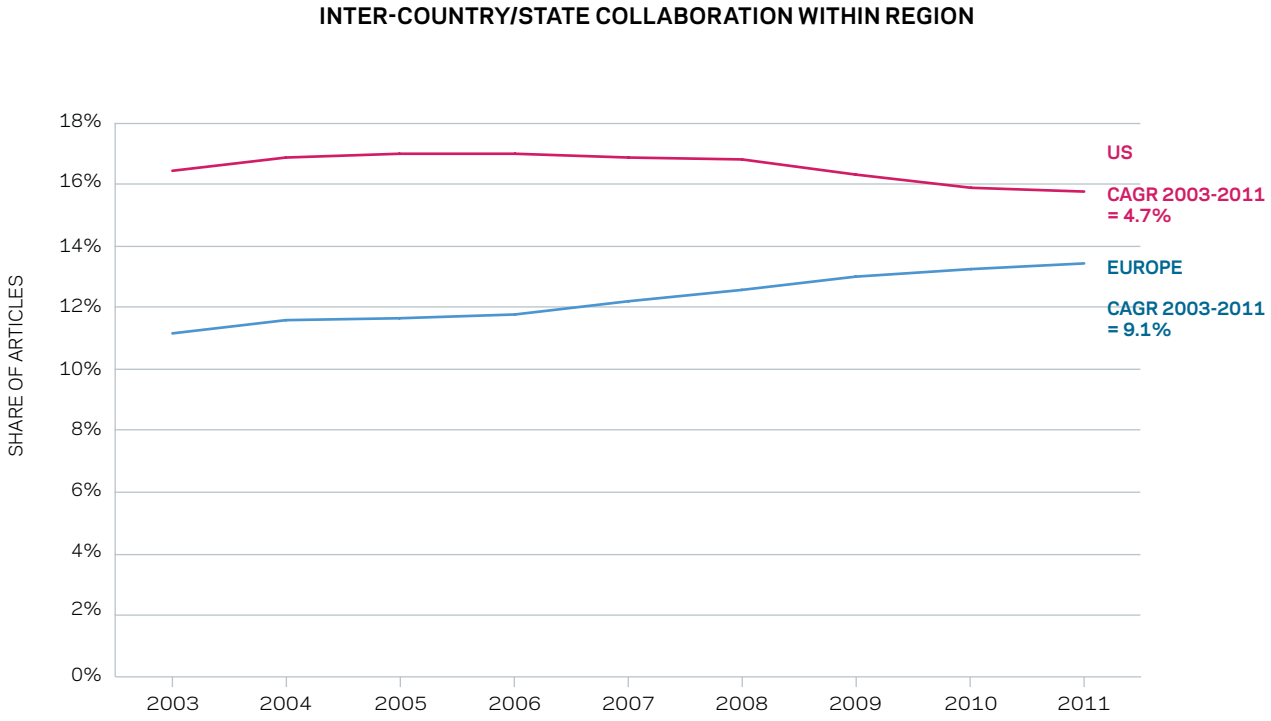


Figure 5 — *European inter-country and US inter-state research collaboration pattern trends, 2003–11. 2003-2011 CAGR is based on absolute numbers and not percentages.*

Outputs included are articles, reviews and conference papers indexed in sources covered by Scopus, primarily journals, conference proceedings, book series, and trade publications. Collaboration is inferred by the pattern of co-authorship as described in the Approach and Definitions section on page 4.

(Fig. 5, which re-plots the relevant data points from Fig. 4 to visualise this trend more clearly); the increase in European inter-country collaboration in the period 2003–11 contrasts with the recently-decreasing levels seen in the analogous inter-state collaboration rate in the US. Thus, the small difference seen between Europe and the US in this regard is narrowing.

While US inter-state collaboration is three percentage points higher than European inter-country collaboration, the difference varies across different disciplines (Fig. 6). The European inter-country collaboration rate is greater than the US inter-state collaboration rate in eight subject fields (most notably Chemical Engineering; Chemistry; Dentistry; Energy; Materials Science; and Physics and Astronomy), while the US inter-state rate exceeds the European inter-country rates in sixteen subject fields (most notably Business, Management and Accounting; Decision Sciences; Economics, Econometrics and Finance; Environmental Science; Health Professions; Immunology and Microbiology; Medicine; Neuroscience; Nursing; Psychology; Social Sciences; and Veterinary).

As shown for European inter-country and US inter-state research collaboration above, outside region research collaboration also varies across different disciplines. In contrast to the results above, a broad subject field view in 2011 shows much greater similarity between the collaboration rates for Europe and the US (Fig. 7). While US outside region collaboration rates are noticeably greater than for Europe in almost all fields (reflecting the much greater overall outside region collaboration rate for the US as shown in Fig. 3), it is only the relatively small 'General' subject field [4] that shows a higher rate in Europe.

[4] This subject field includes high-profile, interdisciplinary weekly journals such as Nature, Science, and Proceedings of the National Academy of Sciences of the United States of America.

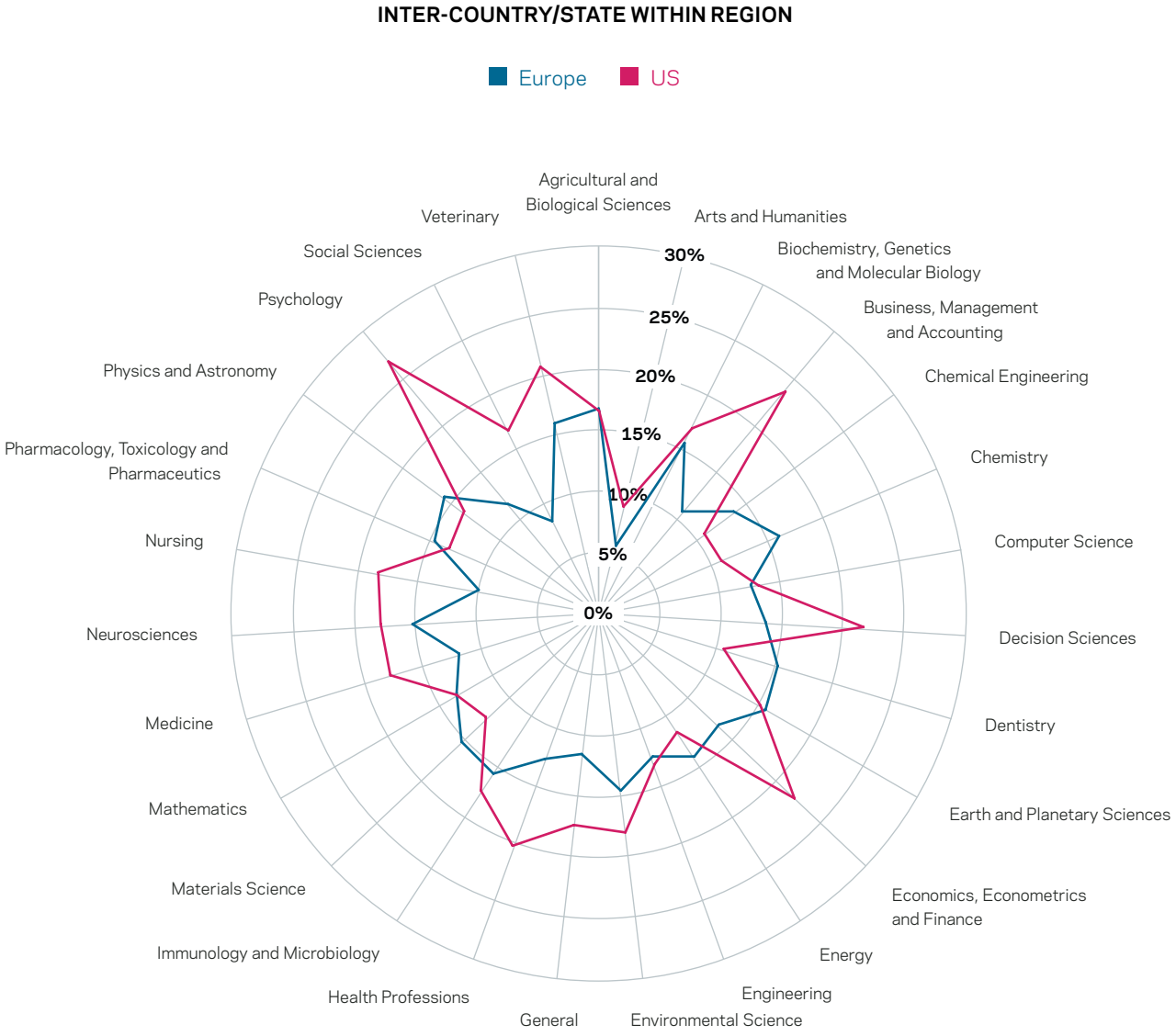


Figure 6 — *European inter-country and US inter-state research collaboration patterns by subject field, 2011.*

Outputs included are articles, reviews and conference papers indexed in sources covered by Scopus, primarily journals, conference proceedings, book series, and trade publications. Collaboration is inferred by the pattern of co-authorship as described in the Approach and Definitions section on page 4.

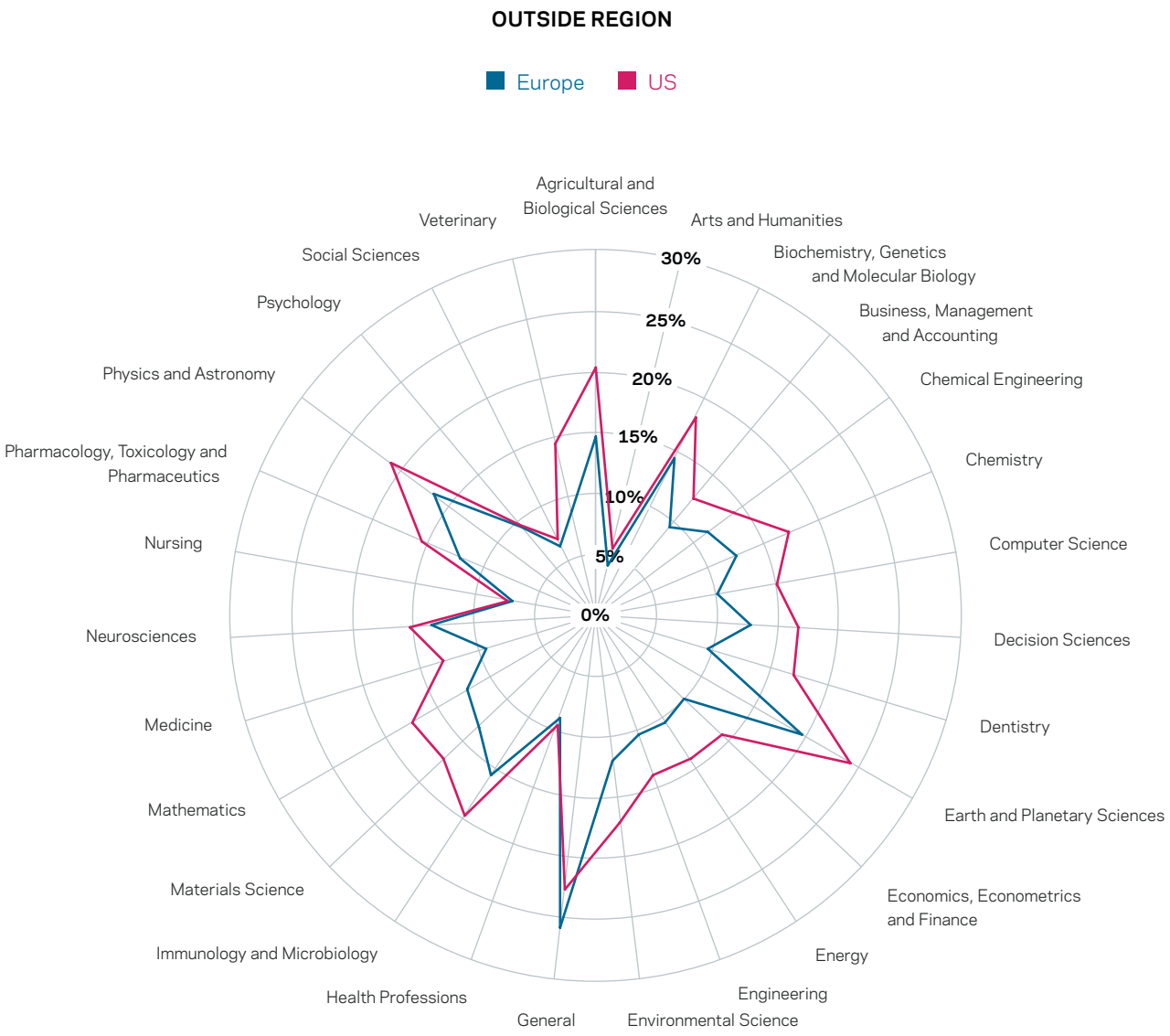


Figure 7 — *European and US outside region research collaboration patterns by subject field, 2011.*

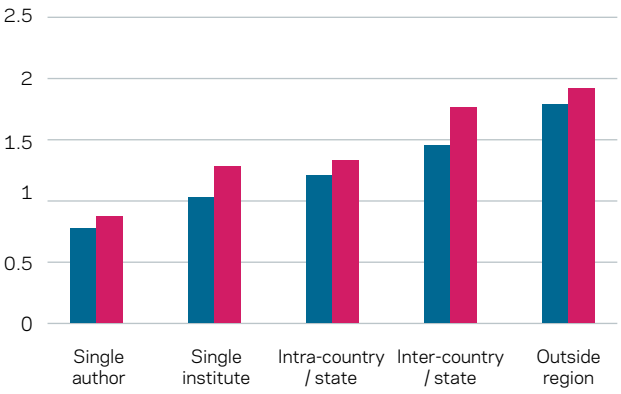
Outputs included are articles, reviews and conference papers indexed in sources covered by Scopus, primarily journals, conference proceedings, book series, and trade publications. Collaboration is inferred by the pattern of co-authorship as described in the Approach and Definitions section on page 4.

1.2 RESEARCH COLLABORATION IMPACT IN EUROPE AND THE US

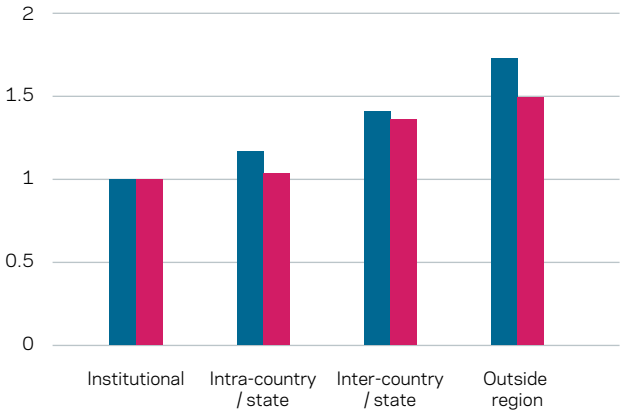
Numerous studies have shown that research outputs that represent collaboration, particularly if that is international collaboration, have a higher citation impact than those that do not [5]. Citation impact is often used as a proxy for research impact and quality, but citation rates differ between research fields owing to underlying disciplinary differences in publication and citation practices. As such, the use of a field-weighted citation impact metric has been adopted here, because it allows direct comparison between entities (such as countries) with different research foci. Figure 8 left shows that citation impact grows as the geographical extent of collaboration increases – for both Europe and the US the highest citation scores are for publications involving researchers from outside these regions.

Figure 8 right presents the information in Figure 8 left in a slightly different way by considering the impact of different collaborations relative to single institution collaboration. This shows that in Europe, collaboration between institutions within a single European country (intra-country) is associated with significantly higher field-weighted citation impact than single institution collaborations (a 1.17-fold

FIELD-WEIGHTED CITATION IMPACT
PER COLLABORATION TYPE (2007-2011)



FWCI FOLD INCREASE OVER INSTITUTIONAL COLLABORATION



FWCI FOLD INCREASE OVER INSTITUTIONAL COLLABORATION

	Institutional	Intra-country / state	Inter-country / state	Outside region
EUROPE	1	1.17	1.41	1.73
US	1	1.03	1.37	1.49

Figure 8 — *European and US field-weighted citation impact by collaboration type, 2007-2011, (left) absolute values per collaboration type, (right) fold increase over institutional collaboration.*

Outputs included are articles, reviews and conference papers indexed in sources covered by Scopus, primarily journals, conference proceedings, book series, and trade publications. Collaboration is inferred by the pattern of co-authorship as described in the Approach and Definitions section on page 4. Field-weighted citation impact is shown for the 2007-2011 datapoint in a) (defined as a five year weighted impact, counting weighted citations received in 2007 up to 4 complete calendar years afterwards to documents published in the same year 2007, plus weighted citations received in 2008 + up to 4 complete calendar years afterwards to documents published in 2008, etc. This total of weighted citations is subsequently divided by the number of documents published in 2007-2011) as well as b) indexed to a value of 1 for institutional collaboration for both Europe and the US.

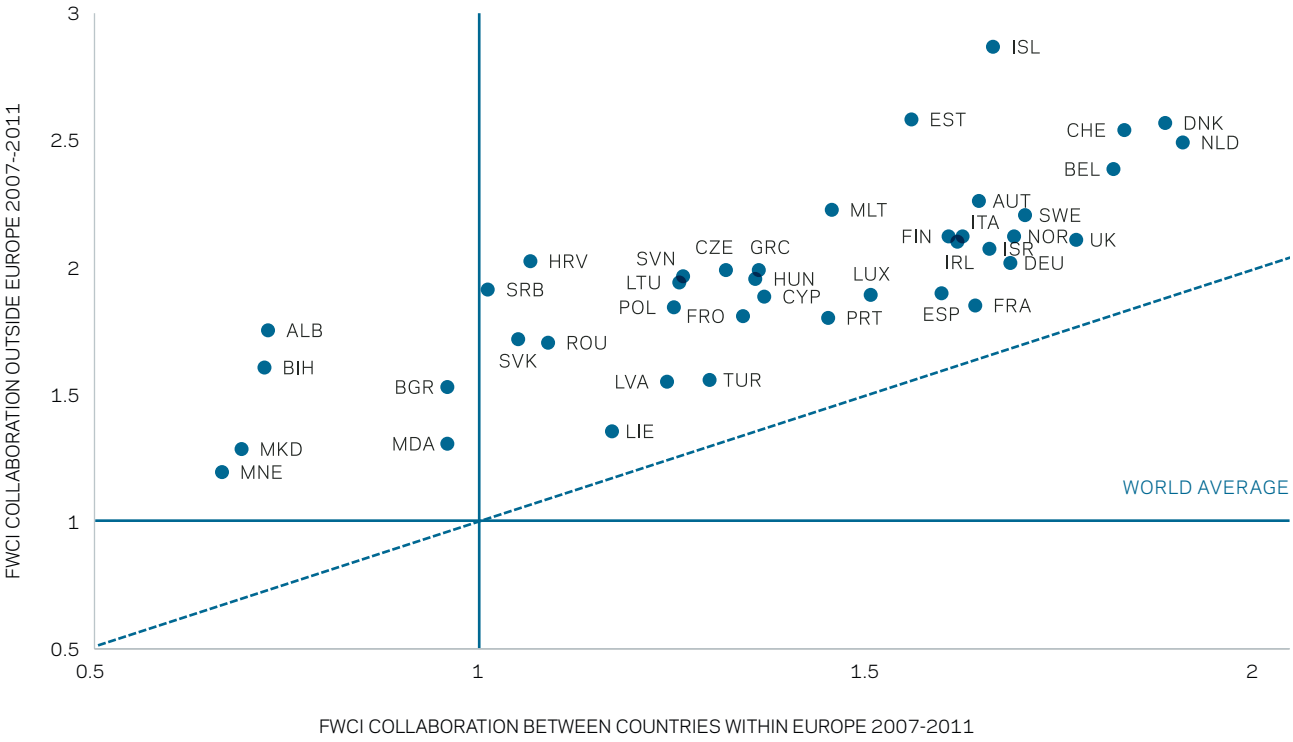


Figure 9 — *European country (above) and US state (next page) field-weighted citation impact by collaboration type, 2007-2011. Country and state codes with full country and state names are listed in Appendix A.*

Outputs included are articles, reviews and conference papers indexed in sources covered by Scopus, primarily journals, conference proceedings, book series, and trade publications. Collaboration is inferred by the pattern of co-authorship as described in the Approach and Definitions section on page 4. Field-weighted citation impact is shown for the 2007-2011 datapoint (defined as a five year weighted impact, counting weighted citations received in 2007 up to 4 complete calendar years afterwards to documents published in the same year 2007, plus weighted citations received in 2008 + up to 4 complete calendar years afterwards to documents published in 2008, etc. This total of weighted citations is subsequently divided by the number of documents published in 2007-2011).

increase), while the difference between these two categories is smaller in the US (1.03-fold). However, both Europe and the US see a similar boost from inter-country collaboration across Europe or inter-state collaboration across the US (1.41- and 1.37-fold, respectively), and further gains still from collaboration outside of Europe or outside of the US. The impact for European researchers collaborating outside of Europe is especially large at 1.73-fold compared to that for the US (1.49-fold). Thus, both Europe and the US benefit most by collaborating outside their regions, but the relative advantage of this is particularly strong for Europe.

The boost in field-weighted citation impact of outside region collaboration over inter-country or inter-state collaboration is observed for all European countries and all US states, as shown in Figure 9. In these charts, the field-weighted citation impact of the inter-country or inter-state collaborations for each European country or US state is plotted against the field-weighted citation impact of their outside region collaborations. A diagonal line crosses the point of unity and for all countries or states above this line the outside region field-weighted citation impact is greater than that of the inter-country or inter-state value. For European countries, the outside region value is always greater than the world average of 1.0 even when the inter-country value is less than 1.0 (for Albania, Bulgaria, Bosnia and Herzegovina, Moldova, FYR Macedonia, and Montenegro). For US states, both the outside region and the inter-state field-weighted citation impact values are well above 1.0, but in all cases the outside region values are much higher. Clearly, for both European countries and US states, collaboration outside the region is associated with the greatest citation performance.

[5] Glänzel, W. (2001) "National characteristics in international scientific co-authorship relations" *Scientometrics* 51(1) pp. 69–115; Levitt, J.M. & Thelwall, M. (2010) "Does the higher citation of collaborative research differ from region to region? A case study of Economics" *Scientometrics* 85(1) pp. 171–183; Guerrero Bote, V. P., Olmeda-Gómez, C. and de Moya-Anegón, F. (2012) "Quantifying the benefits of international scientific collaboration" *J. Am. Soc. Inf. Sci.* doi: 10.1002/asi.22754

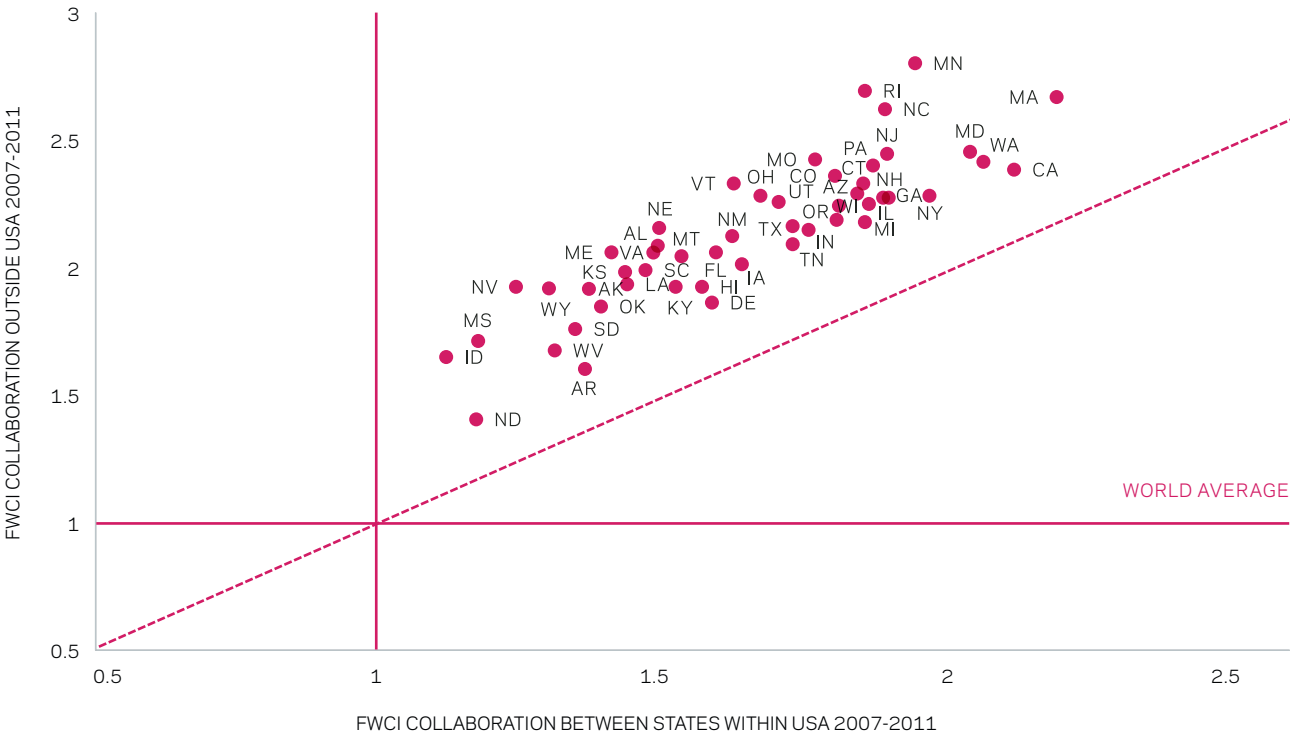


Figure 9 continued from previous page.

1.3 RESEARCH COLLABORATION NETWORKS WITHIN EUROPE AND THE US

The most prolific collaboration partner countries in Europe are shown in Table 1 (left) on page 19, with the volume of research outputs co-authored between them and the field-weighted citation impact of these same outputs. The large research nations lead the table, as expected when using an indicator that correlates closely with total research output volume, and the field-weighted citation impact of these collaborative papers are typically 2.5-3-fold higher than the global average.

The origin of the partners in any research collaboration may have a profound effect on the outcomes, from abstract contributions such as the mixing of different research approaches and traditions through to the more prosaic, such as access to research sites or samples. The sheer volume of research outputs produced by the largest research nations in the world means that international collaborations are most obvious between these countries, but collaborations involving less productive nations may nevertheless have great impact. As such, an indicator – called Salton's measure – of the strength of the collaborative ties between country or state pairs that normalises by the volume of output of both partners has also been adopted here. Salton's measure is calculated by dividing the number of collaborative publications by the geometric mean of the total publication outputs of the two partners [6] - hence it is a size-independent indicator of numbers of collaborations. Table 1 (right) therefore presents a more nuanced view of European international collaboration. While some of the same collaborations between larger research nations are still represented as being of a significant relative magnitude (such as Germany with Switzerland, and Germany with Austria), some much smaller but very close collaborative ties are brought to the fore, such as that between Slovakia and the Czech Republic or Sweden and Denmark, reflecting in both cases a shared (sociocultural) history as well as geographic proximity. In only the smallest pairing represented in this table is the field-weighted citation impact of the co-authored outputs less than the global baseline of 1.000: Serbia with Montenegro.

Similar tables have been produced for the US and can be found in Appendix C. As noted for European countries above, the most prolific collaboration partners amongst US states are those with large research bases overall, and the collaborative outputs show very high field-weighted citation impact (all but one of the top 20 pairings with a field-weighted citation impact above 3). Again, like the European pattern, those US states with high values for Salton's measure include some relatively smaller collaboration pairings – including Virginia with Maryland, North Carolina with Maryland, Colorado with California, and California with Arizona – which also reflect a degree of geographic proximity. Appendix C lists the collaboration pairs between European countries with other countries outside Europe and for US states with countries outside the US. Clearly, the US is an important partner for Europe's collaboration outside the region, with the top seven most prolific pairs representing collaboration between a European country on the one hand and the US on the other. When looking at the top 20 based on Salton's measure, this picture changes since it takes a country's output volume into consideration and so de-emphasises the US as a European partner somewhat. However, collaboration between the UK and the US remains the strongest link.

A holistic view of the relationships between all collaborative pairings between European countries is revealed by a network map of these connections in the period 2007–2011, with each country (node) connected by lines (edges) weighted by Salton's measure and coloured by the field-weighted citation impact of the collaborative research outputs (Fig. 10). The network map shows the complex nature of research collaboration across Europe, with a clear centre of well-connected countries (typically with high field-weighted citation impact of the collaborative research outputs) and a periphery of developing scientific nations with lower-impact linkages. The map also reveals some very clear sub-networks: for example, the close ties between the three Baltic 2004 EU accession countries, Latvia, Lithuania and Estonia

Most prolific pairs of collaboration countries within Europe, 2007-2011

Rank	Country 1	Country 2	Publications 2007-2011	FWCI 2007-2011
1	UK	DEU	41,778	2.73
2	FRA	DEU	32,400	2.69
3	UK	FRA	31,180	2.83
4	DEU	CHE	26,217	2.45
5	ITA	UK	25,389	2.66
6	ITA	FRA	24,065	2.65
7	ITA	DEU	23,921	2.83
8	NLD	DEU	22,417	2.87
9	NLD	UK	21,821	3.11
10	UK	ESP	20,669	2.59
11	FRA	ESP	18,441	2.54
12	ESP	DEU	17,801	2.68
13	ITA	ESP	16,802	2.58
14	DEU	AUT	16,057	2.24
15	FRA	CHE	15,480	2.72
16	UK	CHE	15,014	3.21
17	FRA	BEL	13,748	2.64
18	NLD	FRA	13,163	3.11
19	SWE	UK	12,917	3.10
20	SWE	DEU	11,923	2.93

Highest international collaboration strength pairs

Country 1	Country 2	Publications 2007-2011	FWCI 2007-2011	Salton's measure (S)
DEU	CHE	26,217	2.45	0.0908
DEU	AUT	16,057	2.24	0.0755
SVK	CZE	2,652	1.43	0.0744
NLD	BEL	10,690	2.75	0.0734
UK	DEU	41,778	2.73	0.0687
NLD	DEU	22,417	2.87	0.0660
FRA	DEU	32,400	2.69	0.0643
FRA	BEL	13,748	2.64	0.0636
SWE	DNK	6,001	2.71	0.0631
SRB	MNE	248	0.75	0.0630
SWE	NOR	5,470	2.46	0.0628
FRA	CHE	15,480	2.72	0.0626
ITA	FRA	24,065	2.65	0.0624
NLD	UK	21,821	3.11	0.0621
UK	FRA	31,180	2.83	0.0598
GRC	CYP	1,129	1.89	0.0592
SWE	FIN	5,349	2.56	0.0578
ITA	UK	25,389	2.66	0.0545
ITA	CHE	11,748	2.92	0.0532
ITA	DEU	23,921	2.83	0.0531

Table 1 — *Collaboration partnerships between European countries, 2007-2011. Pairings are sorted by the count of co-authored publications (left) or Salton's measure of collaboration strength (right). Country codes with full country names are listed in Appendix A.*

Outputs included are articles, reviews and conference papers indexed in sources covered by Scopus, primarily journals, conference proceedings, book series, and trade publications. Collaboration is inferred by the pattern of co-authorship as described in the Approach and Definitions section on page 4. Co-authored publications, Salton's measure and field-weighted citation impact are for the 2007-2011 datapoint (defined as a five year weighted impact, counting weighted citations received in 2007 up to 4 complete calendar years afterwards to documents published in the same year 2007, plus weighted citations received in 2008 + up to 4 complete calendar years afterwards to documents published in 2008, etc. This total of weighted citations is subsequently divided by the number of documents published in 2007-2011).

(linked to the rest of the countries in the map mainly through their near neighbour Finland) and several Balkan nations connected to the centre of the map largely via five more 2004 accessions: Poland, Hungary, Slovenia, Slovakia and the Czech Republic. Geopolitical, historical and linguistic ties are evident also: for example, the close pairing of Portugal and Spain on the Iberian peninsula, or the clear cluster of the Nordic countries (Denmark, Norway, Sweden, Finland, and Iceland). The highest-impact collaborations are typically found in the core of the map, where the largest and most prolific research nations are found; however, even the least-connected countries in the map collaborated with at least 21 other countries.

Figure 11 shows a similar network map of the collaborative connections between the states of the US. Like the European country map, the US map displays a clear separation between the states of the highly-collaborative centre and those of the less-connected periphery. However, many of the states at the core of the map, which again constitutes the highest-impact area of the map, are not in close geographical proximity to each other (for example, California and Washington on the west coast, Texas and Florida on the south coast, and New York, Pennsylvania, Massachusetts, New Jersey, Maryland and Washington DC on the eastern seaboard). Other sub-networks do appear to follow more clearly geopolitical and historic ties, such as the southern states of Kentucky, Tennessee, Mississippi, Louisiana, Alabama, Georgia and South Carolina.

[6] Salton's measure is an indicator of collaboration strength (S) between entity x and entity y = (Co-authored papers xy/sqrt of product total papers xy). Glänzel, W. (2001), National characteristics in international scientific co-authorship relations. *Scientometrics* 51(1), 69-115

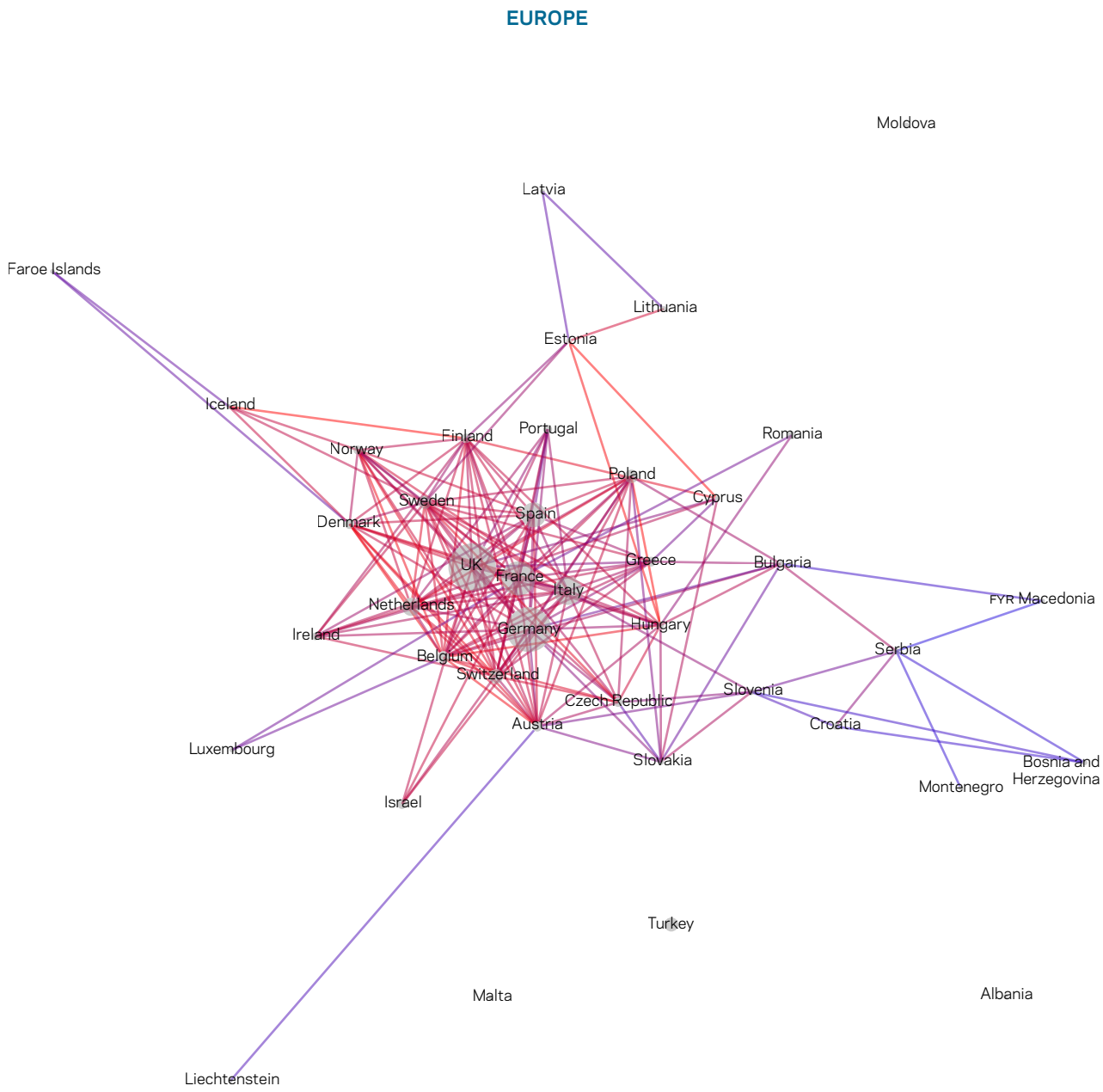


Figure 10 — *Network map of research collaboration between European countries, 2007-2011.*

Outputs included are articles, reviews and conference papers indexed in sources covered by Scopus, primarily journals, conference proceedings, book series, and trade publications. Collaboration is inferred by the pattern of co-authorship as described in the Approach and Definitions section on page 4. Nodes represent countries sized to represent total research outputs and are connected by edges weighted by Salton's measure and coloured by field-weighted citation impact of the collaborative research outputs (range of values 8.438 for most red to 0.890 for most blue). Collaborations below a limit of 0.015 are suppressed for visual clarity. Research outputs, Salton's measure and field-weighted citation impact are for the 2007-2011 datapoint (defined as a five year weighted impact, counting weighted citations received in 2007 up to 4 complete calendar years afterwards to documents published in the same year 2007, plus weighted citations received in 2008 + up to 4 complete calendar years afterwards to documents published in 2008, etc. This total of weighted citations is subsequently divided by the number of documents published in 2007-2011).

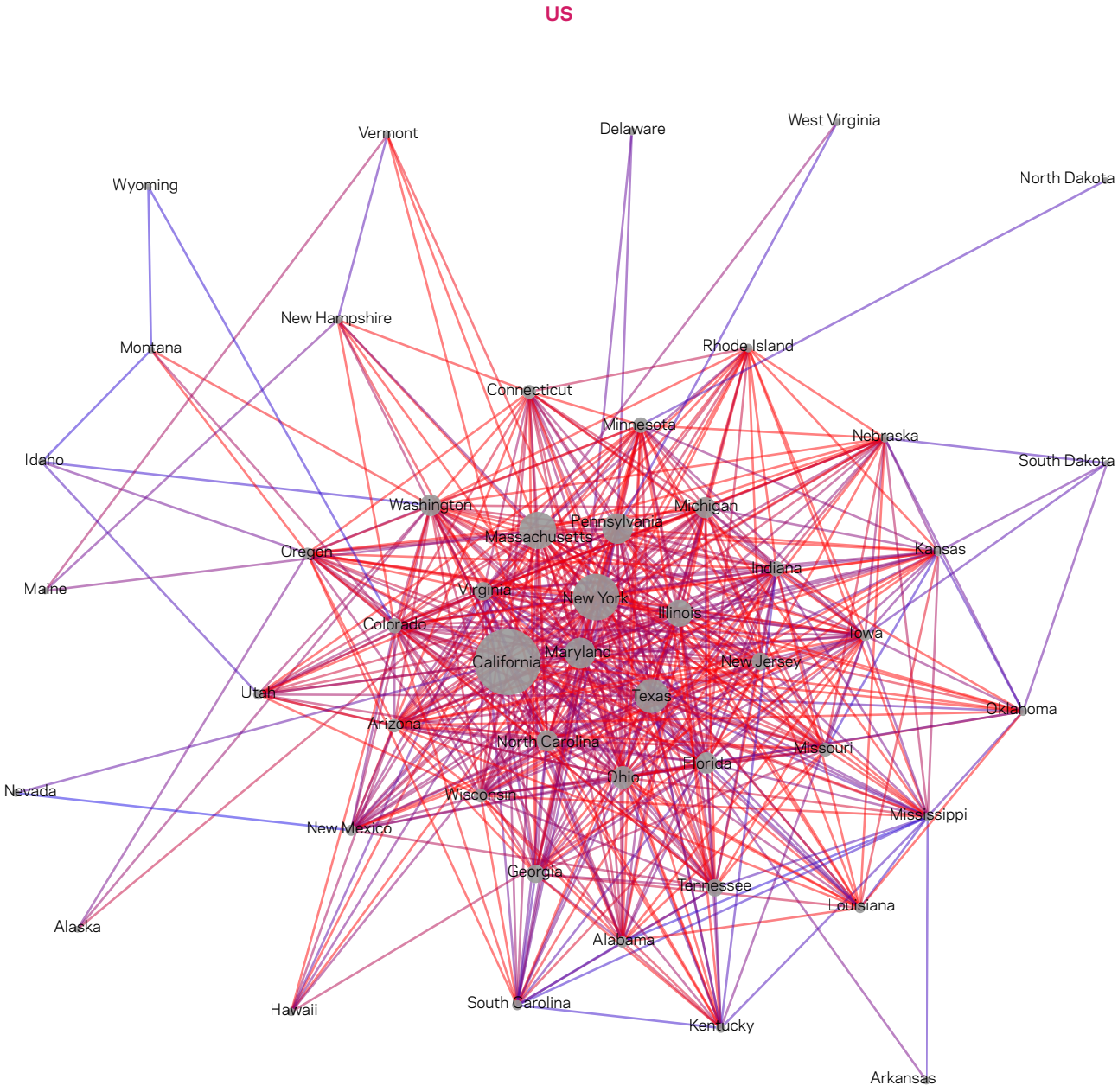


Figure 11 — *Network map of research collaboration between US states, 2007-2011.*

Outputs included are articles, reviews and conference papers indexed in sources covered by Scopus, primarily journals, conference proceedings, book series, and trade publications. Collaboration is inferred by the pattern of co-authorship as described in the Approach and Definitions section on page 4. Co-authored publications, Salton's measure and field-weighted citation impact are for the 2007-2011 datapoint (defined as a five year weighted impact, counting weighted citations received in 2007 up to 4 complete calendar years afterwards to documents published in the same year 2007, plus weighted citations received in 2008 + up to 4 complete calendar years afterwards to documents published in 2008, etc. This total of weighted citations is subsequently divided by the number of documents published in 2007-2011).

1.4 RESEARCH COLLABORATION IN DETAIL: CASE STUDIES FOR THE NETHERLANDS, SWITZERLAND, CZECH REPUBLIC, TURKEY, ALBANIA AND FYR MACEDONIA

Detailed analysis suggests that for different countries within Europe, collaboration pairings with other countries may bring differential outcomes for each partner in terms of the field-weighted citation impact of the resulting outputs. For example, for some European countries the greatest potential for increased field-weighted citation impact would come from collaborating more frequently with other countries in Europe, whereas for others, collaborating outside of Europe would bring maximum citation impact. It is acknowledged of course that increasing citation impact is not a means to an end, but can be correlated with the underlying quality, importance and/or usefulness of research.

The following six countries were selected to illustrate these different scenarios. For each an analysis has been performed on the 20 largest collaboration partner countries and the field-weighted citation impact associated with the collaborative outputs [7], and how this relates to the overall field-weighted citation impact of each partner country. The first example investigates the Netherlands' collaboration partners more closely (Fig. 12). In this chart, the field-weighted citation impact of the collaborative outputs with each partner is plotted against the field-weighted citation impact of these outputs *relative* to the field-weighted citation impact of *all* internationally collaborative outputs from that partner. As such, countries plotted in the upper right quadrant have collaborative outputs with a field-weighted citation impact greater than that of the Netherlands' value for all collaborative outputs, and also greater than that of the value for all collaborative outputs for each partner country. Countries in the lower left quadrant have the opposite pattern, and those in the upper left and lower right have collaborative outputs with a field-weighted citation impact greater than that of the partner but not the Netherlands or the Netherlands but not the partner, respectively. For the Netherlands, collaborations that generate the highest volume of outputs are also associated with field-weighted citation impact greater than that of the Netherlands' average for international collaborations and also for each of the partners too; none of the 20 largest collaboration partners falls into the other three quadrants. The Netherlands realises high impact in collaborations with many European countries, such as the UK, Germany and France, but also the US and Brazil, Japan and Australia.

Displaying the results for all collaboration partners, not just the largest, it is clear that not all collaborations for the Netherlands have a positive effect (Fig. 13). Many collaboration partners fall into the upper left quadrant, meaning that although the collaboration increases the partner's field-weighted citation impact, it does not increase that of the Netherlands. A smaller number of collaborations also fall into the lower left quadrant, representing outputs with a field-weighted citation impact lower than that for both the Netherlands and the partner country.

[7] In this analysis, a hypothetical article that has three authors, one from the Netherlands, one from Switzerland and one from the US, would be counted twice on the map for the Netherlands: once as a collaboration between the Netherlands and Switzerland, and once as a collaboration between the Netherlands and the US.

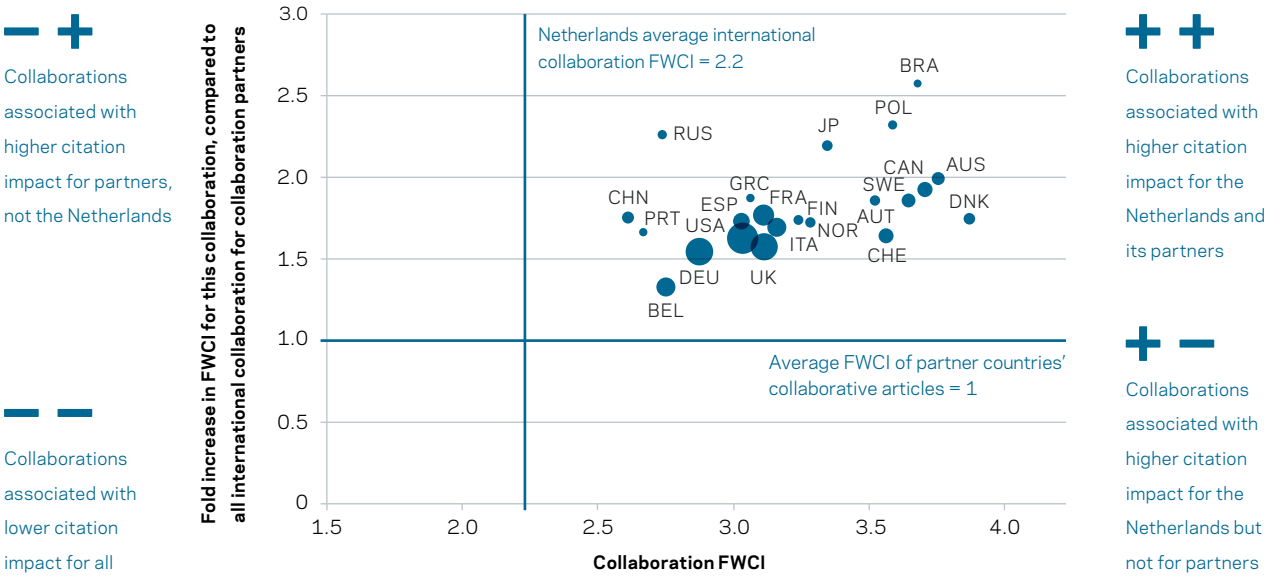


Figure 12 — *Citation impact of collaborative outputs between the Netherlands and the 20 largest collaborating countries within and outside region, 2007-2011.*

Outputs included are articles, reviews and conference papers indexed in sources covered by Scopus, primarily journals, conference proceedings, book series, and trade publications. Collaboration is inferred by the pattern of co-authorship as described in the Approach and Definitions section on page 4. Co-authored publications (proportional to bubble size) and field-weighted citation impact are for the 2007-2011 datapoint (defined as a five year weighted impact, counting weighted citations received in 2007 up to 4 complete calendar years afterwards to documents published in the same year 2007, plus weighted citations received in 2008 + up to 4 complete calendar years afterwards to documents published in 2008, etc. This total of weighted citations is subsequently divided by the number of documents published in 2007-2011).

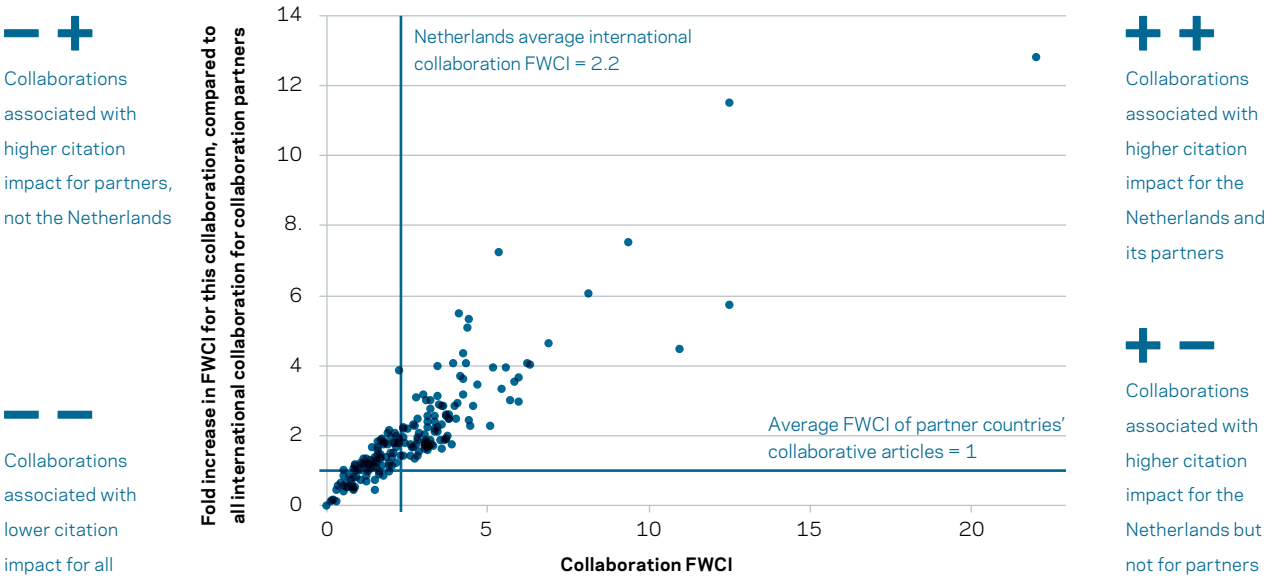


Figure 13 — *Citation impact of collaborative outputs between the Netherlands and all collaborating countries within and outside region, 2007-2011.*

Outputs included are articles, reviews and conference papers indexed in sources covered by Scopus, primarily journals, conference proceedings, book series, and trade publications. Collaboration is inferred by the pattern of co-authorship as described in the Approach and Definitions section on page 4. Co-authored publications (proportional to bubble size) and field-weighted citation impact are for the 2007-2011 datapoint (defined as a five year weighted impact, counting weighted citations received in 2007 up to 4 complete calendar years afterwards to documents published in the same year 2007, plus weighted citations received in 2008 + up to 4 complete calendar years afterwards to documents published in 2008, etc. This total of weighted citations is subsequently divided by the number of documents published in 2007-2011).

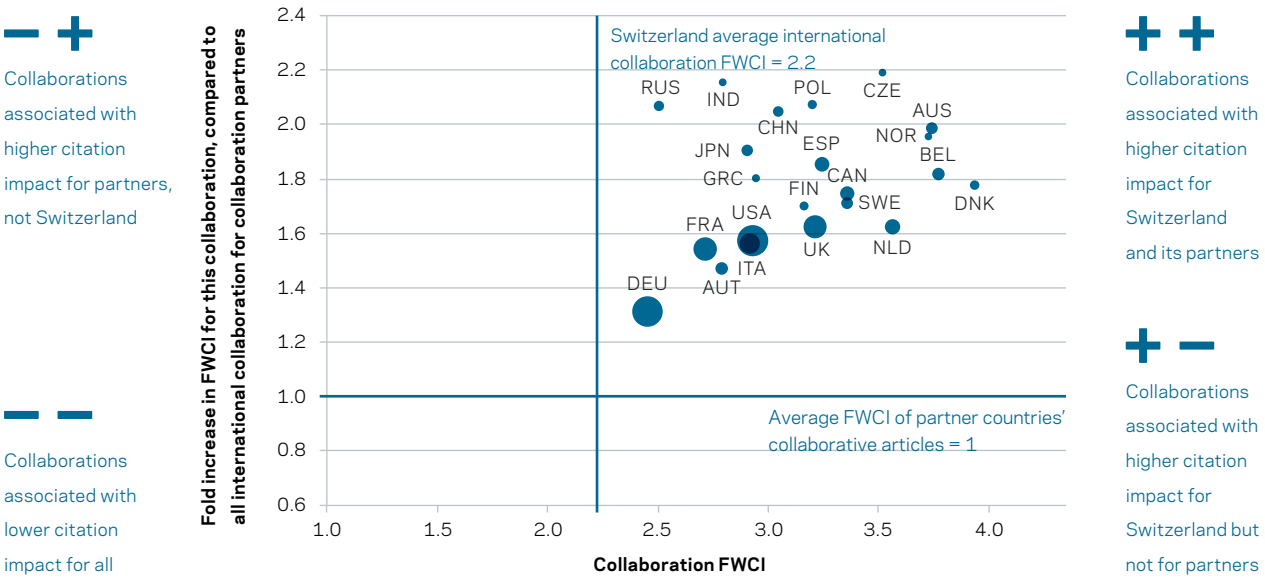


Figure 14 — *Citation impact of collaborative outputs between Switzerland and the 20 largest collaborating countries within and outside region, 2007-2011.*

Outputs included are articles, reviews and conference papers indexed in sources covered by Scopus, primarily journals, conference proceedings, book series, and trade publications. Collaboration is inferred by the pattern of co-authorship as described in the Approach and Definitions section on page 4. Co-authored publications (proportional to bubble size) and field-weighted citation impact are for the 2007-2011 datapoint (defined as a five year weighted impact, counting weighted citations received in 2007 up to 4 complete calendar years afterwards to documents published in the same year 2007, plus weighted citations received in 2008 + up to 4 complete calendar years afterwards to documents published in 2008, etc. This total of weighted citations is subsequently divided by the number of documents published in 2007-2011).

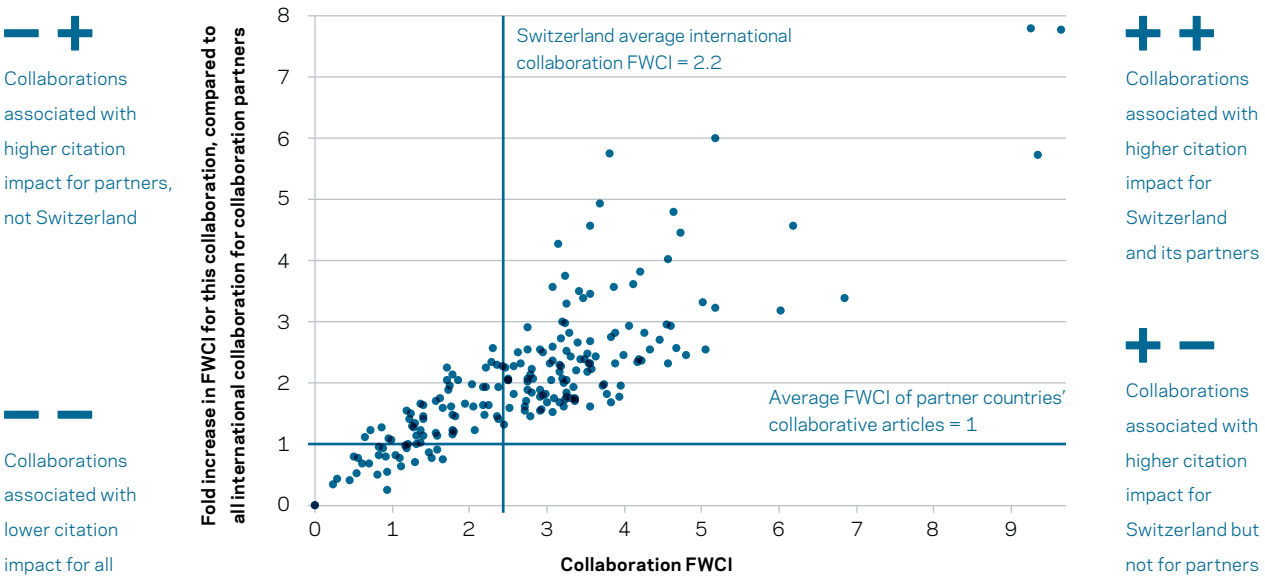


Figure 15 — *Citation impact of collaborative outputs between Switzerland and all collaborating countries within and outside region, 2007-2011.*

Outputs included are articles, reviews and conference papers indexed in sources covered by Scopus, primarily journals, conference proceedings, book series, and trade publications. Collaboration is inferred by the pattern of co-authorship as described in the Approach and Definitions section on page 4. Co-authored publications (proportional to bubble size) and field-weighted citation impact are for the 2007-2011 datapoint (defined as a five year weighted impact, counting weighted citations received in 2007 up to 4 complete calendar years afterwards to documents published in the same year 2007, plus weighted citations received in 2008 + up to 4 complete calendar years afterwards to documents published in 2008, etc. This total of weighted citations is subsequently divided by the number of documents published in 2007-2011).

A second example is Switzerland (Fig. 14), where all of its most prolific collaborations are also in the upper right quadrant and reflect an increased field-weighted citation impact for both parties. Again, when expanding the scope of the analysis to all collaboration partners (Fig. 15), many partnerships fall into the upper left and lower left quadrants, but none are in the lower right quadrant. Like the Netherlands, Switzerland's most prolific collaborations are diverse and international in character.

For the Czech Republic, the situation is slightly different (Fig. 16). All but one of the most prolific collaboration partners is located in the upper right quadrant, with Slovakia instead showing a pattern where the collaboration represents a relatively higher field-weighted citation impact than the average for international collaboration for Slovakia but not for the Czech Republic. When including all collaborations (Fig. 17), the distribution of partners on the chart suggests two main outcomes of collaborations with the Czech Republic: either those in the upper right quadrant which represent an increased field-weighted citation impact for both partners, or those in the lower left quadrant reflecting the opposite outcome. For the Czech Republic, the citation impact outcomes of international collaboration are typically positive for either both partners or for neither.

Turkey shows a slightly different pattern again, with all of its most prolific collaboration partners appearing in the upper right quadrant except for the US, which instead appears in the lower right quadrant and indicates that the collaborative outputs have a higher field-weighted citation impact than the average for all international collaborations for Turkey, but lower than that of all international collaborations for the US (Fig. 18). Encompassing all collaborations, the distribution of collaboration partners is quite similar to that for the Czech Republic, with most falling into the upper right and lower left quadrants (Fig. 19).

The two final examples are for Albania and FYR Macedonia, which differ considerably from the case studies above. For both countries, the majority of their largest collaboration partners fall into the lower right quadrant of the chart, reflecting the situation where the collaborative outputs have a field-weighted citation impact greater than that of Albania or FYR Macedonia's average for internationally collaborative outputs, but which is much lower than that of the partner. For both Albania and FYR Macedonia, there are also countries that appear in the upper right and lower left quadrants, reflecting field-weighted citation impacts either greater than or less than those of both partners respectively. No collaboration partners appear in the upper left quadrant. For both Albania and FYR Macedonia, given that collaborations with all but the largest partners are represented by very low number of outputs, charts of citation impact of collaborative outputs with all collaborating countries within and outside are not shown here. For Albania and FYR Macedonia, the citation impact outcomes from international collaboration are variable, but are typically associated with positive field-weighted citation impact from their own perspective at least.

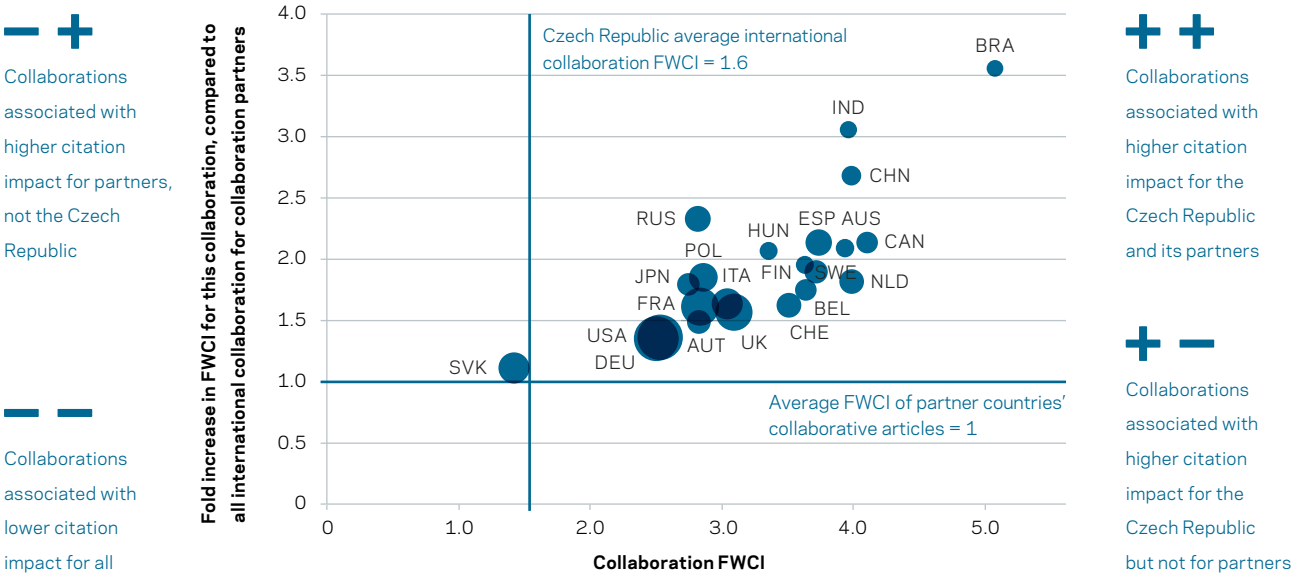


Figure 16 — *Citation impact of collaborative outputs between Czech Republic and the 20 largest collaborating countries within and outside region, 2007-2011.*

Outputs included are articles, reviews and conference papers indexed in sources covered by Scopus, primarily journals, conference proceedings, book series, and trade publications. Collaboration is inferred by the pattern of co-authorship as described in the Approach and Definitions section on page 4. Co-authored publications (proportional to bubble size) and field-weighted citation impact are for the 2007-2011 datapoint (defined as a five year weighted impact, counting weighted citations received in 2007 up to 4 complete calendar years afterwards to documents published in the same year 2007, plus weighted citations received in 2008 + up to 4 complete calendar years afterwards to documents published in 2008, etc. This total of weighted citations is subsequently divided by the number of documents published in 2007-2011).

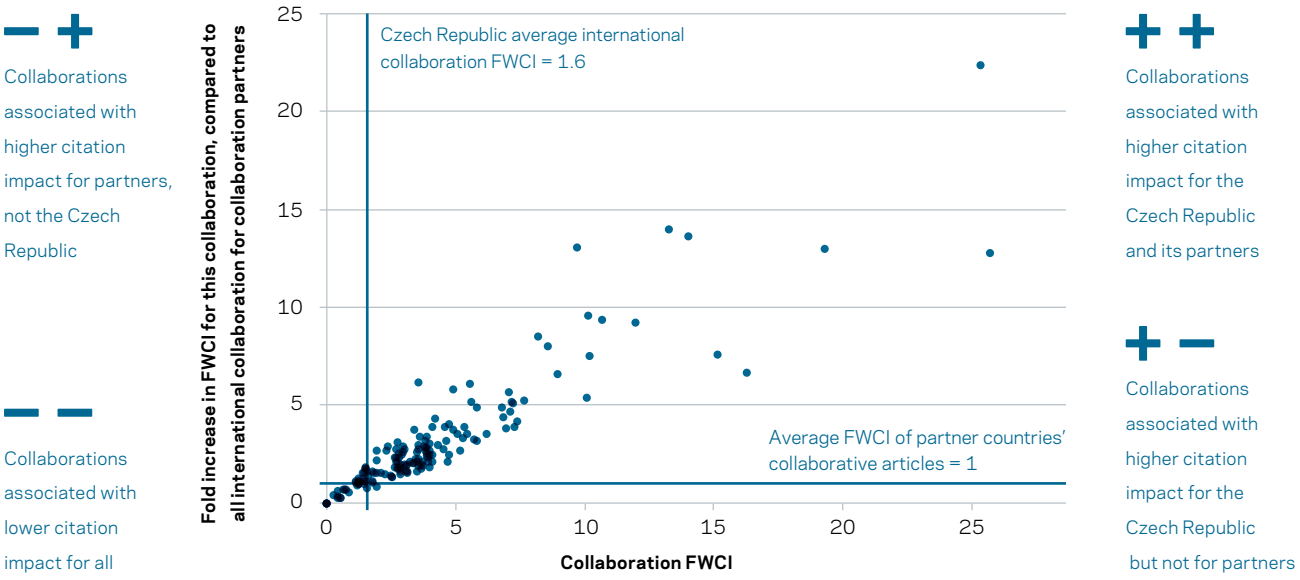


Figure 17 — *Citation impact of collaborative outputs between Czech Republic and all collaborating countries within and outside region, 2007-2011.*

Outputs included are articles, reviews and conference papers indexed in sources covered by Scopus, primarily journals, conference proceedings, book series, and trade publications. Collaboration is inferred by the pattern of co-authorship as described in the Approach and Definitions section on page 4. Co-authored publications (proportional to bubble size) and field-weighted citation impact are for the 2007-2011 datapoint (defined as a five year weighted impact, counting weighted citations received in 2007 up to 4 complete calendar years afterwards to documents published in the same year 2007, plus weighted citations received in 2008 + up to 4 complete calendar years afterwards to documents published in 2008, etc. This total of weighted citations is subsequently divided by the number of documents published in 2007-2011).

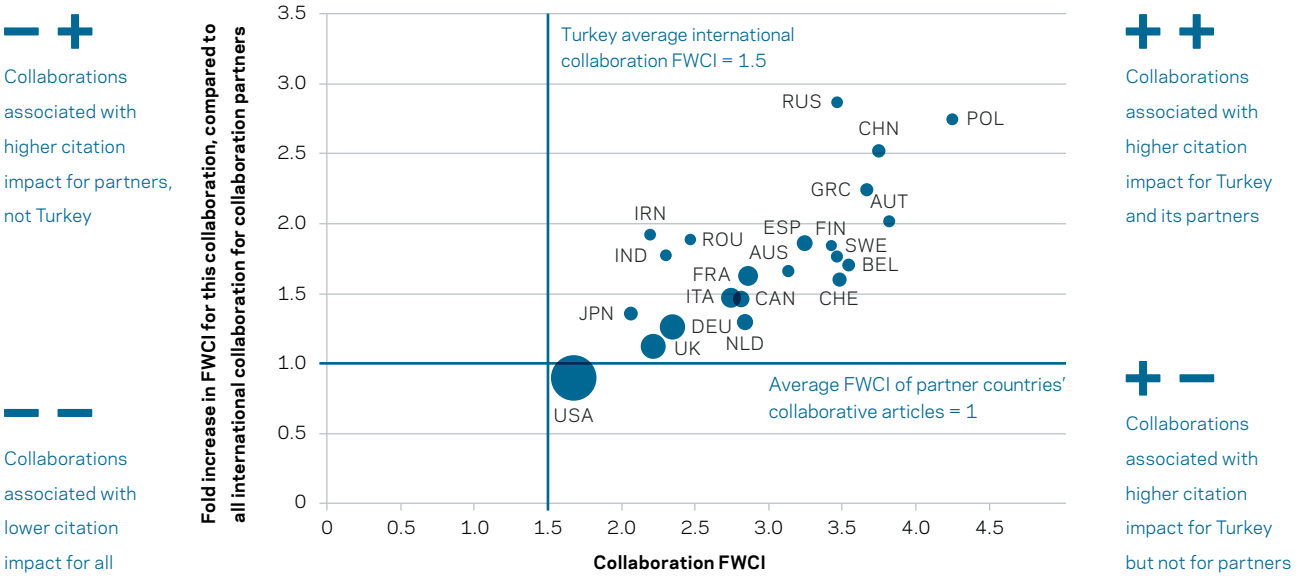


Figure 18 — *Citation impact of collaborative outputs between Turkey and the 20 largest collaborating countries within and outside region, 2007-2011.*

Outputs included are articles, reviews and conference papers indexed in sources covered by Scopus, primarily journals, conference proceedings, book series, and trade publications. Collaboration is inferred by the pattern of co-authorship as described in the Approach and Definitions section on page 4. Co-authored publications (proportional to bubble size) and field-weighted citation impact are for the 2007-2011 datapoint (defined as a five year weighted impact, counting weighted citations received in 2007 up to 4 complete calendar years afterwards to documents published in the same year 2007, plus weighted citations received in 2008 + up to 4 complete calendar years afterwards to documents published in 2008, etc. This total of weighted citations is subsequently divided by the number of documents published in 2007-2011).

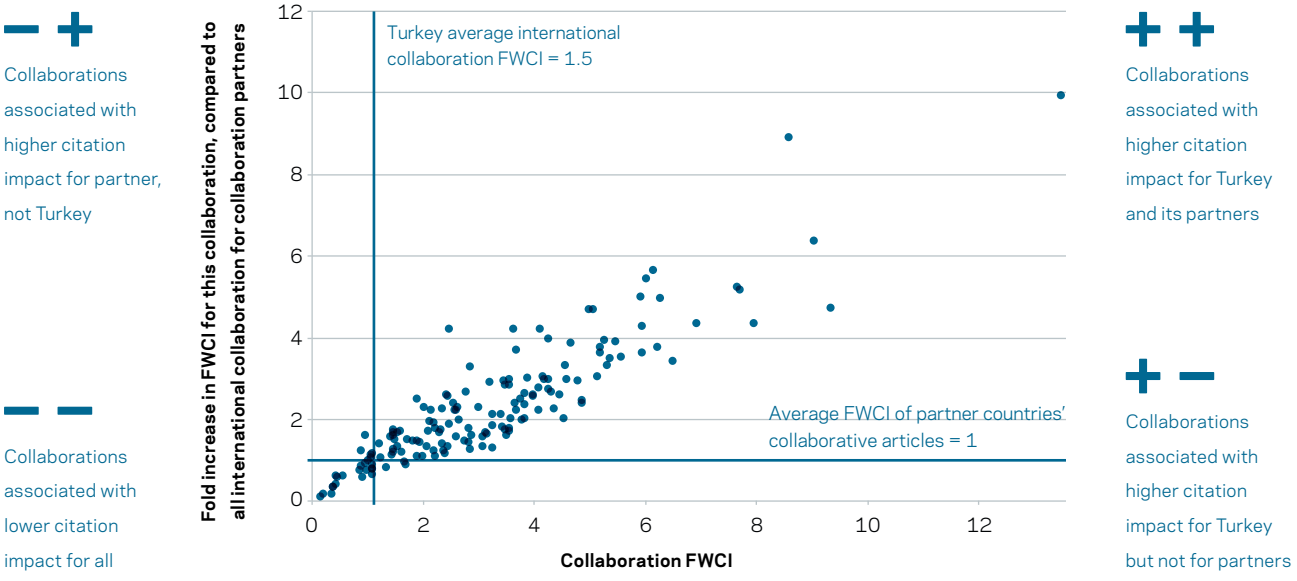


Figure 19 — *Citation impact of collaborative outputs between Turkey and all collaborating countries within and outside region, 2007-2011.*

Outputs included are articles, reviews and conference papers indexed in sources covered by Scopus, primarily journals, conference proceedings, book series, and trade publications. Collaboration is inferred by the pattern of co-authorship as described in the Approach and Definitions section on page 4. Co-authored publications (proportional to bubble size) and field-weighted citation impact are for the 2007-2011 datapoint (defined as a five year weighted impact, counting weighted citations received in 2007 up to 4 complete calendar years afterwards to documents published in the same year 2007, plus weighted citations received in 2008 + up to 4 complete calendar years afterwards to documents published in 2008, etc. This total of weighted citations is subsequently divided by the number of documents published in 2007-2011).

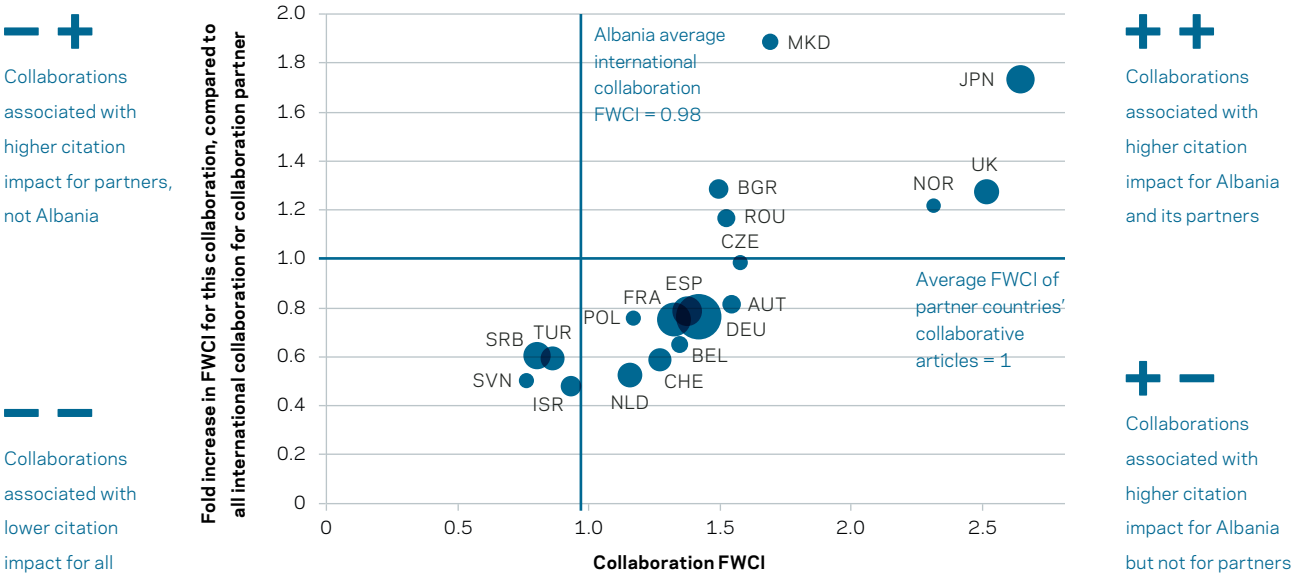


Figure 20 — *Citation impact of collaborative outputs between Albania and the 20 largest collaborating countries within and outside region, 2007-2011.*

Outputs included are articles, reviews and conference papers indexed in sources covered by Scopus, primarily journals, conference proceedings, book series, and trade publications. Collaboration is inferred by the pattern of co-authorship as described in the Approach and Definitions section on page 4. Co-authored publications (proportional to bubble size) and field-weighted citation impact are for the 2007-2011 datapoint (defined as a five year weighted impact, counting weighted citations received in 2007 up to 4 complete calendar years afterwards to documents published in the same year 2007, plus weighted citations received in 2008 + up to 4 complete calendar years afterwards to documents published in 2008, etc. This total of weighted citations is subsequently divided by the number of documents published in 2007-2011).

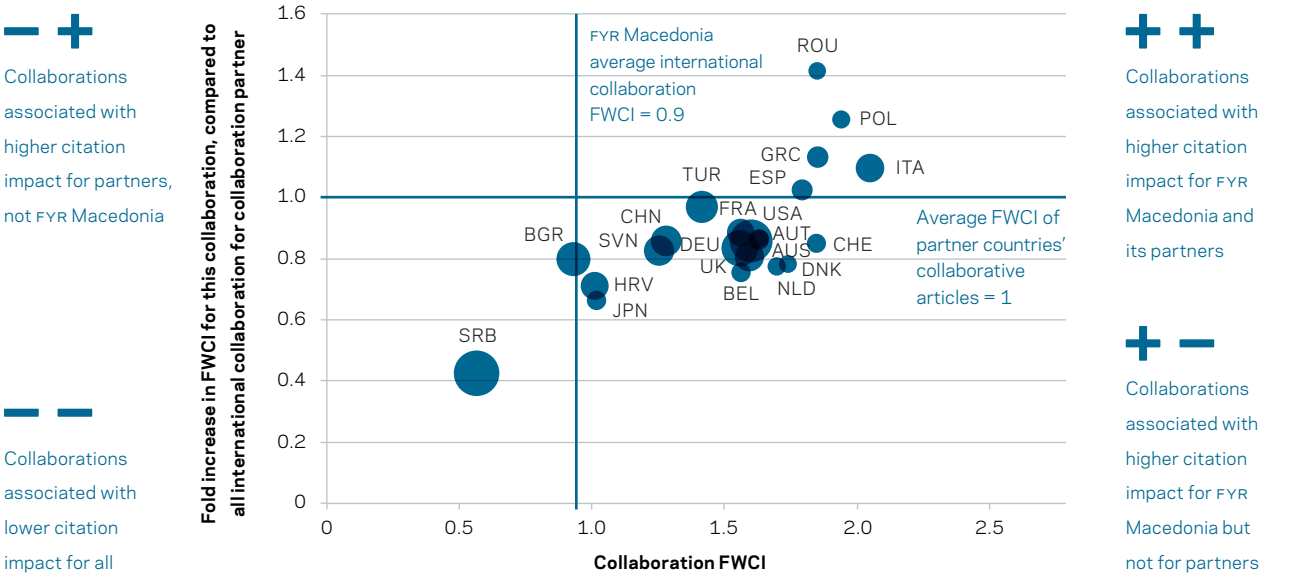


Figure 21 — *Citation impact of collaborative outputs between FYR Macedonia and the 20 largest collaborating countries within and outside region, 2007-2011.*

Outputs included are articles, reviews and conference papers indexed in sources covered by Scopus, primarily journals, conference proceedings, book series, and trade publications. Collaboration is inferred by the pattern of co-authorship as described in the Approach and Definitions section on page 4. Co-authored publications (proportional to bubble size) and field-weighted citation impact are for the 2007-2011 datapoint (defined as a five year weighted impact, counting weighted citations received in 2007 up to 4 complete calendar years afterwards to documents published in the same year 2007, plus weighted citations received in 2008 + up to 4 complete calendar years afterwards to documents published in 2008, etc. This total of weighted citations is subsequently divided by the number of documents published in 2007-2011).

CHAPTER 2

RESEARCHER MOBILITY IN EUROPE AND THE US

INTRODUCTION

In this chapter, we address the following question regarding researcher mobility in Europe and the US:

4. Do European researchers' patterns of mobility between European countries (and the rest of the world) differ from US researchers' patterns of mobility between US states (and the rest of the world)?

To answer this question we consider researchers who have published with affiliations in different states or countries. The data encompass the period 1996 to 2011 and, as a result, provide a snapshot in researcher careers. Researchers may, of course, have published with different affiliations prior to this period; an individual who moves from the US to another country in this period may not have originated in the US, but may instead have moved into the US prior to 1996, only to move once more within the period of observation. Even so, the analysis is consistent for Europe and the US and provides some indication of researcher mobility over a fairly long period of 15 years.

2.1 RESEARCHER MOBILITY CLASSES IN EUROPE AND THE US

The study of researcher mobility is not new, dating back to the post-war era at least when a large number of researchers moved from Europe to the US. For many years, this so-called 'brain drain' was measured using data collected by national statistical agencies on the migration of skilled workers. More recently, the advent of sophisticated abstracting and indexing and citation databases such as Scopus, and the comprehensive and detailed author profiles constructed from them, have permitted a more granular view of the patterns of researcher mobility between institutions, cities, states and countries. An aggregated view of such patterns from Scopus was first presented in a report published in 2011 [8].

Taking all researchers in Europe and the US with active author profiles in the period 1996-2011 inclusive [9], these were classified into three distinct mobility types: sedentary (immobile), inter-country/-state mobility, and mobility outside region. Thus, for a European researcher defined as having moved outside the region, they will have published papers between 1996 and 2011 which identified their affiliations both at a European and a non-European institution. The duration of stay on either side of an inter-country/-state move or outside region move was not considered, since it is not the dynamics of researcher mobility but the relative propensity for mobility which was the focus of this analysis.

Figure 22 (left) shows that the most common mobility class in both Europe and the US is sedentary; that is, researchers with published outputs reflecting only affiliation(s) within a single European country or within a single US state during the period 1996–2011 inclusive. However, Europe has a significantly higher proportion of its researchers in this mobility class than the US (56.8% versus 31.7%). There is a somewhat higher rate of outside region mobility observed for researchers in the US than researchers in Europe (8.4% versus 5.5%).

The most striking difference is between the inter-country mobility rate for European researchers, at just 6.8%, compared with the inter-state mobility rate for US researchers, at 22.2%. Comparison with the 2011 collaboration pattern data reproduced from Figure 3 and displayed in a different format in Figure 22 right shows that the pattern of collaboration between countries in Europe is much more similar to

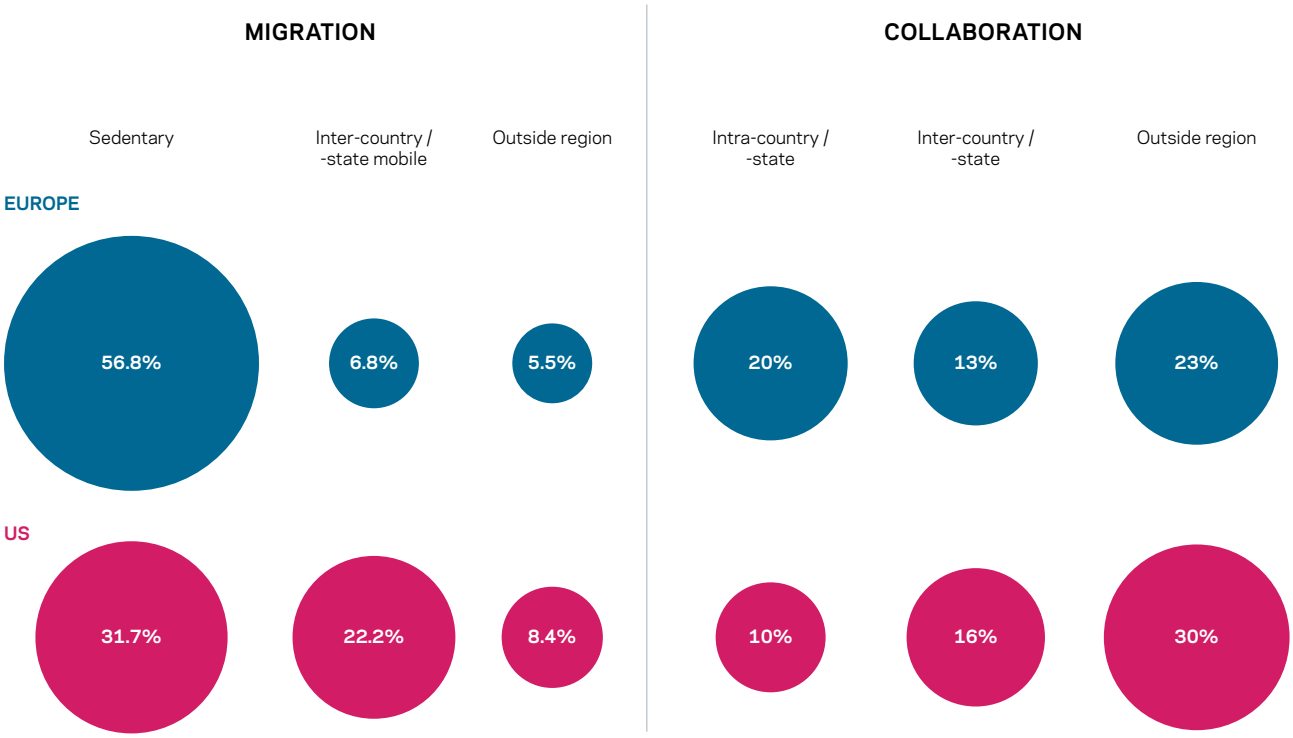


Figure 22 — *(left) European and US researcher mobility classes, 1996–2011 and (right) collaboration patterns, 2007-2011.*

Outputs included are articles, reviews and conference papers indexed in sources covered by Scopus, primarily journals, conference proceedings, book series, and trade publications. Mobility classes are inferred by the pattern of affiliation changes over time as described in the Approach and Definitions section on page 4; bubbles reflect the proportion of active researchers in each mobility class and do not add to 100% owing to the exclusion of researchers exhibiting patterns of transitory mobility. Collaboration is inferred by the pattern of co-authorship as described in the Approach and Definitions section on page 4, and are reproduced from Fig.3.

that between states in the US than we find for researcher mobility.

A more detailed look at the sedentary researcher rate by European country and US state is shown in Figure 23 and reveals great heterogeneity in both regions. In Europe, those countries with the highest proportions of sedentary researchers (i.e. those remaining within the same European country between 1996 and 2011) include several of the 2004 EU accessions (Latvia, Lithuania, Estonia, Poland, Slovenia, and Czech Republic), the 2007 EU accession, Romania, and the recent EU accession, Croatia, but also southern European countries such as Italy, Spain and Greece (Fig 23 left). These disparities may reflect cultural and linguistic diversity across Europe, but policy and administrative factors, such as lack of pension portability, may also play a part. In contrast, those US states with the highest proportions of sedentary researchers (i.e. those remaining within the same US state between 1996 and 2011) include those with the greatest concentration of large research-intensive universities, such as California, Texas, Massachusetts, New York and Pennsylvania (Fig 23 right).

[8] Department for Business, Innovation & Skills (2011) *International Comparative Performance of the UK Research Base*, pg 36.

[9] Active authors are defined as those with publication output frequencies that typically indicate career researchers pursuing a programme of research, specifically, those with at least one publication in the period 2007-11 and at least 15 publications in the period 1996-2011.

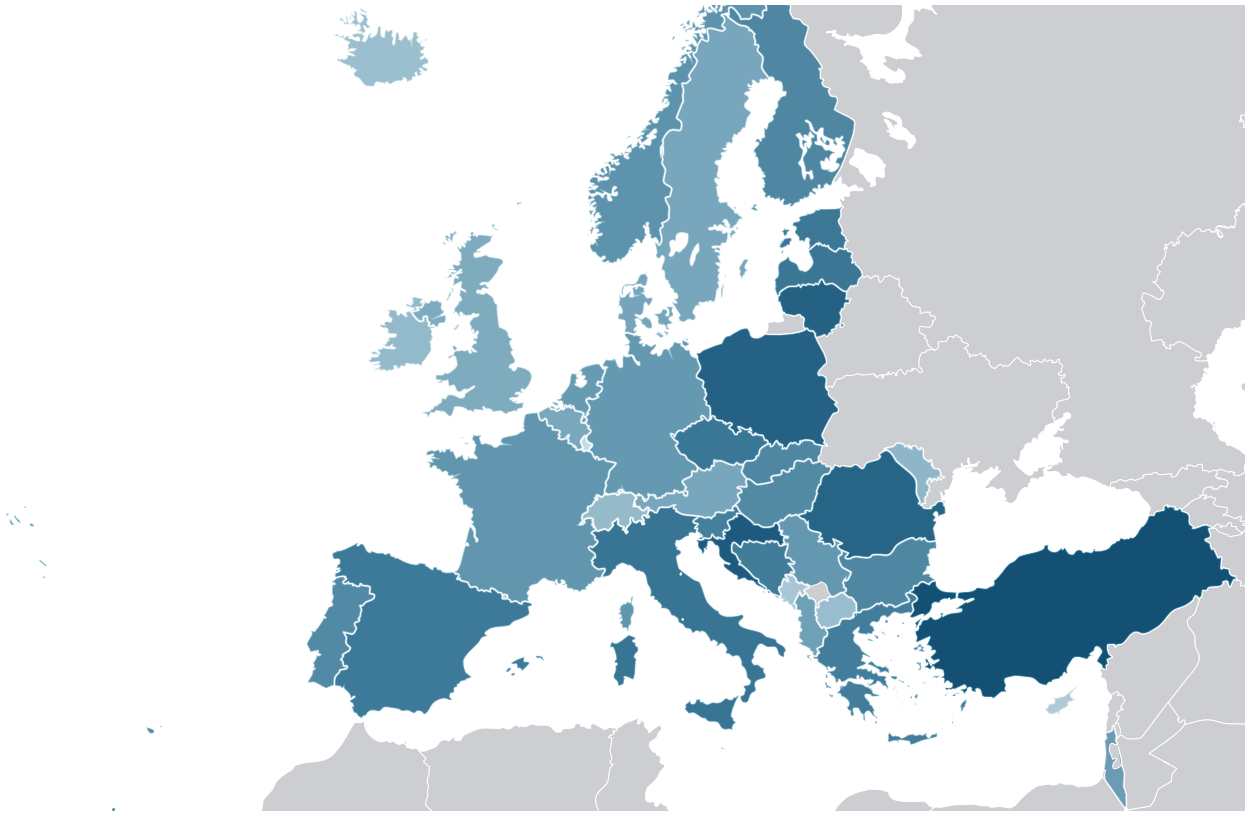


Figure 23 — *Sedentary (immobile) researcher distributions by European country (above) and US state (next page), 1996–2011.*

Outputs included are articles, reviews and conference papers indexed in sources covered by Scopus, primarily journals, conference proceedings, book series, and trade publications. Mobility classes are inferred by the pattern of affiliation changes over time as described in the Approach and Definitions section on page 4; shading reflects the proportion of active researchers in the sedentary mobility class from black (100%) to white (0%) (countries in grey in the European map are not included in study). Note that for visual clarity the scale used in the European and US maps are not the same and thus are not directly comparable.

Country rankings

1	Turkey	72.00%
2	Croatia	65.95%
3	Lithuania	62.35%
4	Poland	62.08%
5	Romania	60.56%
6	Italy	53.00%
7	Czech Republic	52.30%
8	Latvia	51.89%
9	Estonia	51.40%
10	Spain	50.84%
11	Bosnia and Herzegovina	49.15%
12	Greece	48.85%
13	Slovenia	48.37%
14	Bulgaria	44.56%
15	Finland	44.33%
16	Slovakia (Slovak Republic)	44.16%
17	Hungary	43.20%
18	Portugal	43.09%
19	Norway	39.47%
20	France	38.01%
21	Serbia	37.46%
22	Germany	36.81%
23	Netherlands	36.08%
24	Israel	35.00%
25	Albania	34.17%
26	Denmark	31.88%
27	Austria	31.43%
28	Sweden	31.41%
29	Belgium	30.89%
30	United Kingdom	29.53%
31	Malta	25.60%
32	Moldova	25.05%
33	Ireland	23.93%
34	FYR Macedonia	22.28%
35	Iceland	22.00%
36	Montenegro	19.00%
37	Cyprus	17.00%
38	Switzerland	16.17%
39	Luxembourg	11.70%
40	Faroe Islands	8.00%
	Liechtenstein	8.00%

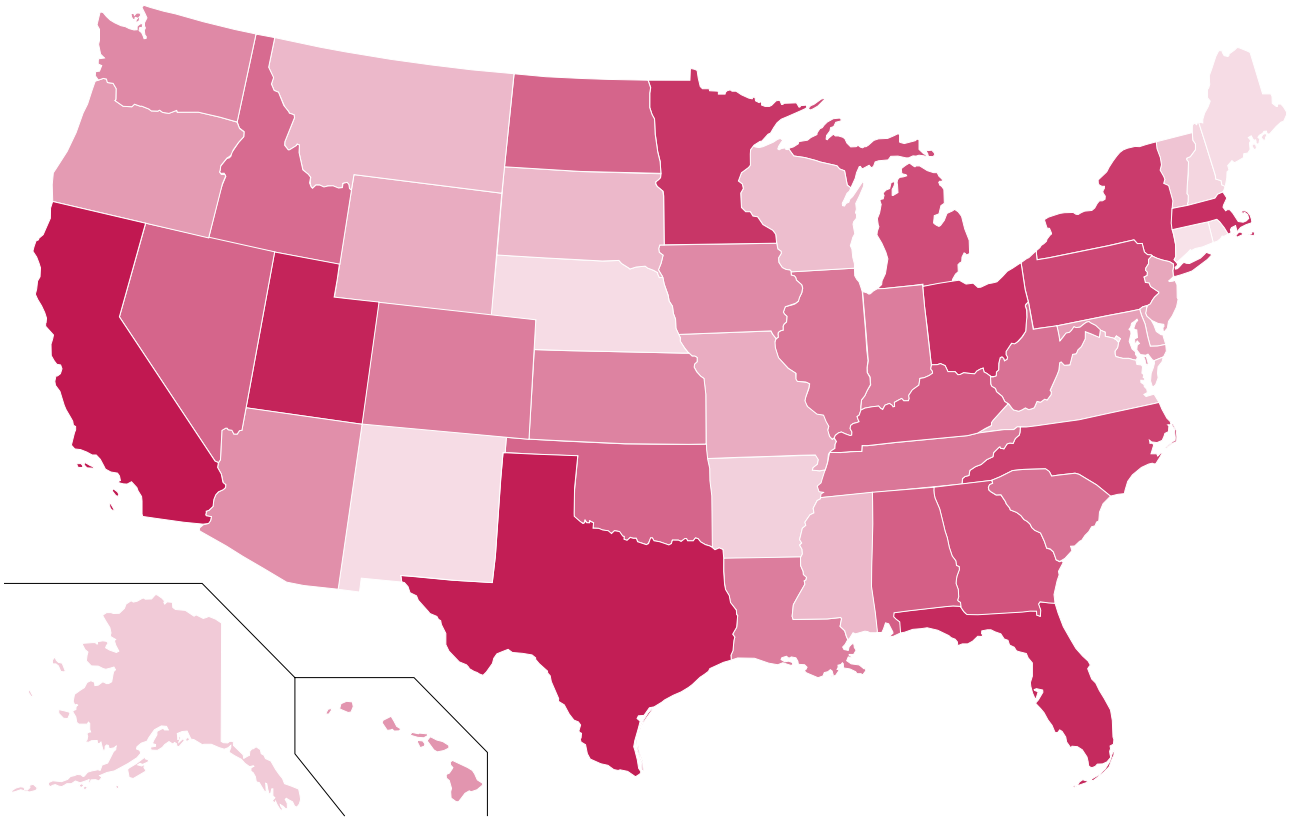


Figure 23 continued from previous page.

State rankings

1	California	24.80%
2	Texas	22.00%
3	Utah	21.90%
4	Florida	21.60%
5	Massachusetts	21.50%
	Ohio	21.50%
6	Minnesota	21.40%
7	New York	21.30%
8	North Carolina	21.20%
9	Pennsylvania	21.10%
10	Michigan	20.90%
11	Georgia	20.70%
12	Kentucky	20.50%
13	Alabama	20.40%
14	Nevada	20.10%
	North Dakota	20.10%
	Oklahoma	20.10%
15	Idaho	20.00%
16	South Carolina	19.80%
	West Virginia	19.80%
17	Illinois	19.40%
	Tennessee	19.40%
18	Colorado	19.00%
	Indiana	19.00%
	Louisiana	19.00%
19	Kansas	18.80%
20	Iowa	18.70%
	Washington	18.70%
21	Arizona	18.50%
22	Hawaii	18.30%
23	Oregon	18.20%
24	Maryland	17.80%
25	New Jersey	17.60%
26	Missouri	17.40%
	Wyoming	17.40%
27	Delaware	17.30%
28	Mississippi	17.20%
	Montana	17.20%
	South Dakota	17.20%
29	Wisconsin	17.00%
30	Vermont	16.90%
	Virginia	16.90%
31	Alaska	16.80%
32	Arkansas	16.70%
33	New Hampshire	16.20%
34	Maine	16.10%
	Nebraska	16.10%
	New Mexico	16.10%
35	Connecticut	16.00%
	Rhode Island	16.00%
36	Washington DC	10.80%

2.2 RESEARCHER MOBILITY AND IMPACT IN EUROPE AND THE US

The relationship between researcher mobility and the country or state's overall field-weighted citation impact differs between Europe and the US. Figure 24 depicts this relationship, showing the percentage of sedentary researchers in European countries or US states in the period 1996-2011 and the field-weighted citation impact of each country or state's entire output in 2007-2011.

For Europe, there is much more variation in terms of percentages of sedentary researchers, ranging from 11% to 66%, compared to 16% to 25% in the US, and with a de-duplicated average of 57% for Europe and 31% for the US (Fig. 23) [10].

There is also slightly more variation in terms of field-weighted citation impact, ranging from 0.5 to almost 2 for Europe and from 1 to 2.2 for the US. For Europe, countries with the highest impact, such as Switzerland, tend to show lower percentages of sedentary researchers. For the US, states with the highest impact, such as California and Massachusetts, tend to show higher percentages of sedentary researchers.

The field-weighted citation impact of the outputs associated with researchers in each mobility class is shown in Figure 25 (right). This shows that for Europe, the small proportions of researchers who have moved jobs between European countries ('inter-country'), or out of Europe ('outside region') are associated with slightly higher field-weighted citation impact than those who remained within the same country ('sedentary'). For the US, the situation is somewhat different: the highest field-weighted citation impact is associated with researchers who moved jobs between states, while those who moved out of the US have a lower value than either those who remained in the same state throughout the period, or those who moved between states within the US.

[10] The averages may seem high in relation to the range. However, this is caused by the de-duplication that occurs when the average for Europe or the US is calculated. Per state or country, the number of sedentary researchers is divided by the total number of active researchers in that state or country. This total number of active researchers includes researchers who move, and they are therefore also counted in the total number of active researchers of the country that they moved to. In order to calculate the average for Europe or the US as a whole, we have de-duplicated this count, including each researcher only once. If the duplicated count of total active researchers would be used, meaning that movers would be double-counted in all countries or states that they have published in, these average percentages would be 40% and 20% respectively, which would make more sense within the range presented here.

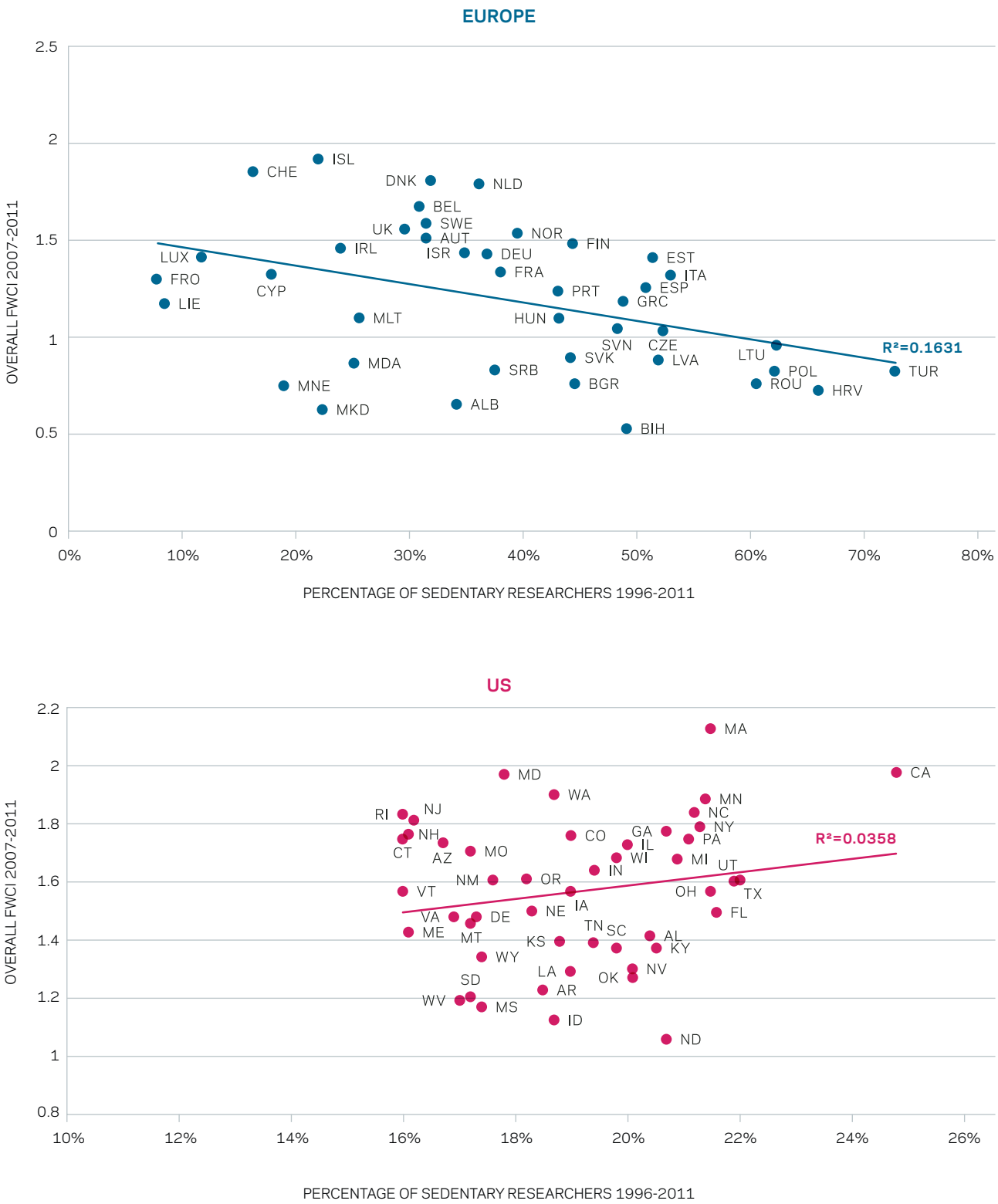


Figure 24 — *Sedentary researcher distributions 1996–2011 and field-weighted citation impact 2007-2011 by European country (upper) and US state (lower).*

Outputs included are articles, reviews and conference papers indexed in sources covered by Scopus, primarily journals, conference proceedings, book series, and trade publications. Mobility classes are inferred by the pattern of affiliation changes over time as described in the Approach and Definitions section on page 4. Field-weighted citation impact is for the 2007-2011 datapoint (defined as a five year weighted impact, counting weighted citations received in 2007 up to 4 complete calendar years afterwards to documents published in the same year 2007, plus weighted citations received in 2008 + up to 4 complete calendar years afterwards to documents published in 2008, etc. This total of weighted citations is subsequently divided by the number of documents published in 2007-2011).

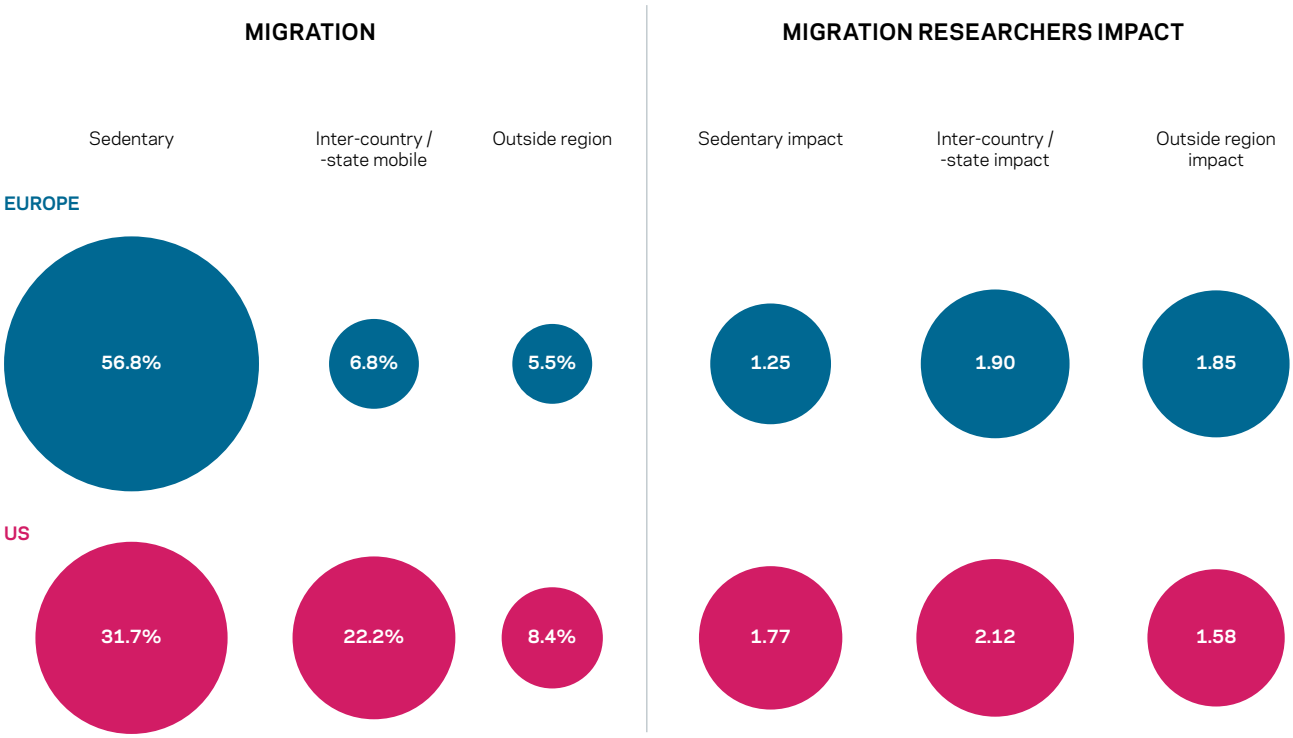
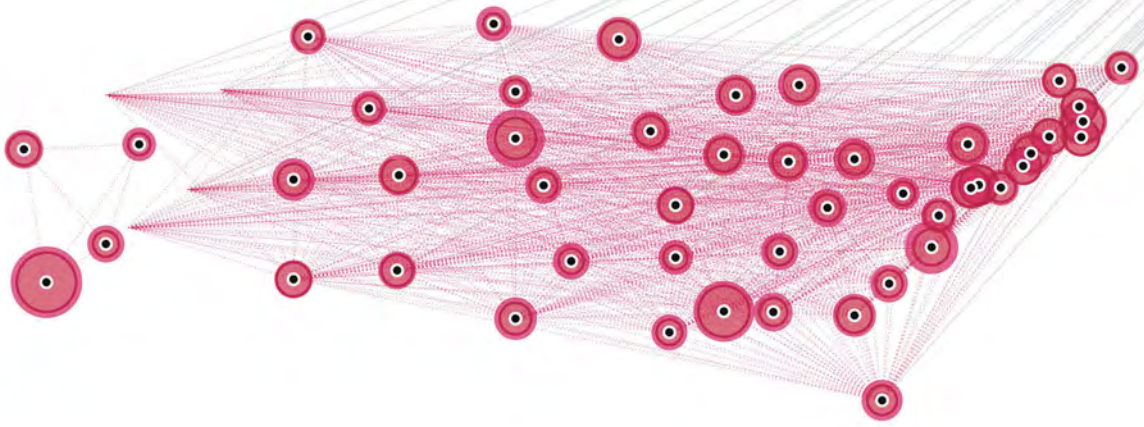


Figure 25 — *(left) Migration patterns (1996-2011) and (right) FWCI (2007-2011) for each category of researchers and their articles for Europe and US.*

CHAPTER 3

CONCLUSIONS



CONCLUSIONS

Whilst recognising that publications are not the only indicator of research collaboration and researcher mobility, through the analyses presented in this report, we have been able to provide an evidence base for answering the questions posed in the Introduction:

1

What is the frequency of research collaboration between countries within Europe and how is this changing? How does this compare with research collaboration between states within the US?

Most of the research outputs produced by Europe represent collaborations (Fig. 3), and 13% of outputs reflect collaborations between researchers based in two or more different European countries (i.e. inter-country collaboration), a figure which is rising each year. Considered analogously, research collaboration between US states (i.e. inter-state collaboration) is of a similar level and has been broadly stable at around 16% since 2003 (Fig. 5). This suggests that the small difference between Europe and the US is diminishing. The extent of European inter-country or US inter-state research collaboration varies across different disciplines, with European inter-country collaboration rates greater than the US inter-state collaboration rate in some fields and the reverse being true in others (Fig. 6).

2

Do the collaborative patterns of European authors with non-European authors (i.e. those in the rest of the world) differ from those of US authors with non-US authors?

International collaboration rates globally have risen in recent years. This trend is reflected also in the tendency for European and US authors to form collaborations that result in co-authored research outputs with researchers outside their own region. While a high and rising proportion of European research outputs represent collaborations with researchers outside Europe, with a similar trend apparent in the US, it is the case that the US is involved in a higher proportion of such collaboration than Europe (Fig. 4). The extent of European or US outside region research collaboration varies across different disciplines, but there is greater similarity between disciplines than for European inter-country and US inter-state research collaboration. Note that US outside region collaboration rates are greater than for Europe in almost all fields (Fig. 7).

3

Do collaborative research outputs have greater citation impact than the non-collaborative outputs for each country within Europe or state within the US?

In Europe, collaboration between institutions within a single European country is associated with significantly higher field-weighted citation impact than single institution collaborations, an effect that is much more modest than for collaboration between institutions within US states (Fig. 8). However, both Europe and the US see a similar boost from inter-country collaboration across Europe or inter-state collaboration across the US. It is noticeable that collaboration outside of the region is particularly rewarding in citation impact terms, especially for Europe. In relative terms, the US benefits from a greater increase in field-weighted citation impact between intra-state and inter-state collaboration, while Europe sees the largest relative increase in the move from inter-country to outside region collaboration.

A closer look at collaboration partners for selected European countries showed that in most cases, the collaboration has a positive effect on the citation impact of both countries. However, collaboration with some of the smaller European countries in terms of research output shows evidence for European capacity building: collaborating with these smaller, often lower impact countries helps to improve their research potential and strengthen Europe as a whole.

4

Do European researchers' patterns of mobility between European countries (and the rest of the world) differ from US researchers' patterns of mobility between US states (and the rest of the world)?

Most researchers in both Europe and the US stayed in the same country or state ('sedentary') between 1996 and 2011, according to the affiliations on their published outputs. However, the percentage remaining sedentary was higher in Europe than in the US (Fig. 22). Conversely, a higher rate of outside region mobility is observed for US researchers than European researchers. Most notable, though, is the striking difference in the inter-country mobility rate for European researchers, which is considerably lower than the inter-state mobility rate for US researchers. Furthermore, those who move have higher citation impacts than those who do not. There is great heterogeneity in the sedentary researcher rate across both European countries and US states (Fig. 23).

APPENDIX A
COUNTRY AND STATE ABBREVIATIONS

Europe defined as consisting of the 41 countries with direct eligibility for Seventh Framework Programme (FP7) funding.

European country	Abbreviation
Albania	ALB
Austria	AUT
Belgium	BEL
Bosnia and Herzegovina	BIH
Bulgaria	BGR
Croatia	HRV
Cyprus	CYP
Czech Republic	CZE
Denmark	DNK
Estonia	EST
Faroe Islands	FRO
Finland	FIN
France	FRA
FYR Macedonia	MKD
Germany	DEU
Greece	GRC
Hungary	HUN
Iceland	ISL
Ireland	IRL
Israel	ISR
Italy	ITA
Latvia	LVA
Liechtenstein	LIE
Lithuania	LTU
Luxembourg	LUX
Malta	MLT
Moldova	MDA
Montenegro	MNE
Netherlands	NLD
Norway	NOR
Poland	POL
Portugal	PRT
Romania	ROM
Serbia	SR
Slovakia (Slovak Republic)	SVK
Slovenia	SVN
Spain	ESP
Sweden	SWE
Switzerland	CHE
Turkey	TUR
United Kingdom	UK

US state	Abbreviation
Alabama	AL
Alaska	AK
Arizona	AZ
Arkansas	AR
California	CA
Colorado	CO
Connecticut	CT
Delaware	DE
Florida	FL
Georgia	GA
Hawaii	HI
Idaho	ID
Illinois	IL
Indiana	IN
Iowa	IA
Kansas	KS
Kentucky	KY
Louisiana	LA
Maine	ME
Maryland	MD
Massachusetts	MA
Michigan	MI
Minnesota	MN
Mississippi	MS
Missouri	MO
Montana	MT
Nebraska	NE
Nevada	NV
New Hampshire	NH
New Jersey	NJ
New Mexico	NM
New York	NY
North Carolina	NC
North Dakota	ND
Ohio	OH
Oklahoma	OK
Oregon	OR
Pennsylvania	PA
Rhode Island	RI
South Carolina	SC
South Dakota	SD
Tennessee	TN
Texas	TX
Utah	UT
Vermont	VT
Virginia	VA
Washington	WA
Washington D.C.	DC
West Virginia	WV
Wisconsin	WI
Wyoming	WY

Code	Country
AFG	Afghanistan
ALB	Albania
DZA	Algeria
ASM	American Samoa
AND	Andorra
AGO	Angola
AIA	Anguilla
ATA	Antarctica
ATG	Antigua and Barbuda
ARG	Argentina
ARM	Armenia
ABW	Aruba
AUS	Australia
AUT	Austria
AZE	Azerbaijan
BHS	Bahamas
BHR	Bahrain
BGD	Bangladesh
BRB	Barbados
BLR	Belarus
BEL	Belgium
BLZ	Belize
BEN	Benin
BMU	Bermuda
BTN	Bhutan
BOL	Bolivia
BIH	Bosnia and Herzegovina
BWA	Botswana
BVT	Bouvet island
BRA	Brazil
IOT	British Indian Ocean Territory
BRN	Brunei Darussalam
BGR	Bulgaria
BFA	Burkina Faso
BDI	Burundi
KHM	Cambodia
CMR	Cameroon
CAN	Canada
CPV	Cape Verde
CYM	Cayman Islands
CAF	Central African Republic
TCD	Chad
CHL	Chile
CHN	China
CXR	Christmas island
CCK	Cocos (keeling) islands
COL	Colombia
COM	Comoros
COG	Congo
COD	Congo, the drc
COK	Cook islands
CRI	Costa rica
CIV	Cote d'ivoire
HRV	Croatia
CUB	Cuba
CYP	Cyprus
CZE	Czech republic
DNK	Denmark
DJI	Djibouti
DMA	Dominica
DOM	Dominican republic
TMP	East Timor
ECU	Ecuador
EGY	Egypt
SLV	El salvador
GNQ	Equatorial guinea
ERI	Eritrea
EST	Estonia
ETH	Ethiopia
FLK	Falkland islands (malvinas)
FRO	Faroe islands
FJI	Fiji
FIN	Finland
FRA	France
FXX	France, metropolitan
GUF	French guiana
PYF	French polynesia
ATF	French southern territories
GAB	Gabon
GMB	Gambia
GEO	Georgia
DEU	Germany
GHA	Ghana
GIB	Gibraltar
GRC	Greece
GRL	Greenland
GRD	Grenada
GLP	Guadeloupe
GUM	Guam
GTM	Guatemala
GIN	Guinea
GNB	Guinea-bissau
GUY	Guyana
HTI	Haiti
HMD	Heard and mc donald islands
VAT	Holy see (vatican city state)
HND	Honduras
HKG	Hong kong
HUN	Hungary
ISL	Iceland
IND	India
IDN	Indonesia
IRN	Iran (islamic republic of)
IRQ	Iraq
IRL	Ireland
ISR	Israel
ITA	Italy
JAM	Jamaica
JPN	Japan
JOR	Jordan
KAZ	Kazakhstan
KEN	Kenya
KIR	Kiribati
PRK	Korea, d.p.r.o.
KOR	Korea, republic of
KWT	Kuwait
KGZ	Kyrgyzstan
LAO	Laos
LVA	Latvia
LBN	Lebanon
LSO	Lesotho
LBR	Liberia
LBY	Libyan arab jamahiriya
LIE	Liechtenstein
LTU	Lithuania
LUX	Luxembourg
MAC	Macau
MKD	FYR Macedonia
MDG	Madagascar
MWI	Malawi
MYS	Malaysia
MDV	Maldives
MLI	Mali
MLT	Malta
MHL	Marshall islands
MTQ	Martinique
MRT	Mauritania
MUS	Mauritius
MYT	Mayotte
MEX	Mexico
FSM	Micronesia, federated states of
MDA	Moldova, republic of
MCO	Monaco
MNG	Mongolia
MNE	Montenegro
MSR	Montserrat
MAR	Morocco
MOZ	Mozambique
MMR	Myanmar (burma)
NAM	Namibia
NRU	Nauru
NPL	Nepal
NLD	Netherlands

Code	Country
ANT	Netherlands Antilles
NCL	New Caledonia
NZL	New Zealand
NIC	Nicaragua
NER	Niger
NGA	Nigeria
NIU	Niue
NFK	Norfolk island
MNP	Northern Mariana Islands
NOR	Norway
OMN	Oman
PAK	Pakistan
PLW	Palau
PAN	Panama
PNG	Papua new guinea
PRY	Paraguay
PER	Peru
PHL	Philippines
PCN	Pitcairn
POL	Poland
PRT	Portugal
PRI	Puerto Rico
QAT	Qatar
REU	Reunion
ROM	Romania
RUS	Russian federation
RWA	Rwanda
KNA	Saint kitts and nevis
LCA	Saint lucia
VCT	Saint vincent and the grenadines
WSM	Samoa
SMR	San marino
STP	Sao tome and principe
SAU	Saudi arabia
SEN	Senegal
SRB	Serbia
SYC	Seychelles
SLE	Sierra leone
SGP	Singapore
SVK	Slovakia (slovak republic)
SVN	Slovenia
SLB	Solomon islands
SOM	Somalia
ZAF	South Africa
SSD	South Sudan
SGS	South Georgia and south s.s.
ESP	Spain
LKA	Sri Lanka
SHN	St. Helena
SPM	St. Pierre and Miquelon
SDN	Sudan
SUR	Suriname
SJM	Svalbard and jan mayen islands
SWZ	Swaziland
SWE	Sweden
CHE	Switzerland
SYR	Syrian Arab republic
TWN	Taiwan, province of china
TJK	Tajikistan
TZA	Tanzania, united republic of
THA	Thailand
TGO	Togo
TKL	Tokelau
TON	Tonga
TTO	Trinidad and Tobago
TUN	Tunisia
TUR	Turkey
TKM	Turkmenistan
TCA	Turks and caicos islands
TUV	Tuvalu
UGA	Uganda
UKR	Ukraine
ARE	United Arab emirates
UK	United kingdom
USA	United states
UMI	U.S. Minor islands
URY	Uruguay
UZB	Uzbekistan
VUT	Vanuatu
VEN	Venezuela
VNM	Viet Nam
VGB	Virgin islands (British)
VIR	Virgin islands (U.S.)
WLF	Wallis and Futuna islands
ESH	Western Sahara
YEM	Yemen
ZMB	Zambia
ZWE	Zimbabwe

APPENDIX B **METHODOLOGY**

Methodology and rationale

Our methodology is based on the theoretical principles and best practices developed in the field of quantitative science and technology studies, particularly in science and technology indicators research. The Handbook of Quantitative Science and Technology Research: The Use of Publication and Patent Statistics in Studies of S&T Systems (Moed, Glänzel and Schmoch, 2004) gives a good overview of this field and is based on the pioneering work of Derek de Solla Price (1978), Eugene Garfield (1979) and Francis Narin (1976) in the USA, Christopher Freeman, Ben Martin and John Irvine in the UK (1981, 1987), and in several European institutions including the Centre for Science and Technology Studies at Leiden University, the Netherlands, and the Library of the Academy of Sciences in Budapest, Hungary.

The analyses of bibliometric data in this report are based upon recognised advanced indicators (e.g., the concept of relative citation impact rates). Our base assumption is that such indicators are useful and valid, though imperfect and partial measures, in the sense that their numerical values are determined by research performance and related concepts, but also by other, influencing factors that may cause systematic biases. In the past decade, the field of indicators research has developed a best practices which state how indicator results should be interpreted and which influencing factors should be taken into account. Our methodology builds on these practices.

Article types

For all bibliometric analysis, only the following document types are considered:

- Article (AR)
- Review (RE)
- Conference Proceeding (CP).

Counting

All analyses make use of whole counting rather than fractional counting. For example, if a paper has been co-authored by one author from the UK and one author from the Netherlands, then that paper counts towards both the publication count of the UK, as well as the publication count of the Netherlands. Total counts for each country are the unique count of publications.

Data Source

The data source for this study is the Scopus abstract and citation database of peer-reviewed research literature, which was developed by and is owned by Elsevier. It is the largest abstract and citation database of peer reviewed research literature in the world, with abstracts and citation information from more than 45 million scientific research articles in 20,000 peer-reviewed journals published by over 5,000 publishers spanning all science sectors, including the Arts & Humanities (Scopus contains more than 3,000 publications in the field of Arts & Humanities). Scopus covers approximately 5900 titles from North America, 8400 from Europe, 2800 from Asia-Pacific and 800 from Latin America and Africa. Scopus.com is used by 1,900 customers, with more than 3 million users in 2010. The average click through to full-text rate is 2.1 million per month, with over 25.5 million in 2010. Scopus currently includes over 47 million publications from more than 4000 global publishers. See http://info.scopus.com for more information.

Publication output: The number of publications per country, which have at least one author affiliated to an institution in that country. A publication which is co-authored by authors from different countries, thus counts towards the publication output of each country.

CAGR: Compound Annual Growth Rate

The Compound Annual Growth Rate is defined as the year-over-year constant growth rate over a specified period of time. Starting with the first value in any series and applying this rate for each of the time intervals yields the amount in the final value of the series.

$$\text{CAGR}(t_0, t_n) = (V(t_n) / V(t_0))^{\frac{1}{t_n - t_0}} - 1$$

$V(t_0)$: start value, $V(t_n)$: finish value, $t_n - t_0$: number of years.

Field Weighted Citation Impact: A measure of citation impact, based on the average number of citations received by a group of publications compared to the world number of citations received by the same type of publications. This metric is field weighted in that it adjusts for differing citation practices in different subject fields and therefore for the different subject emphases of comparator countries. FWCI for each year looks at the citations that publications in that particular year have received in that same year up to 4 years after publication, and compares this value of actual citations to the number of expected citations based on the subject in question, the year in question and the article types in question.

Salton's measure of collaboration strength (S) between entity x and entity y = (Co-authored papers xy/squareroot of product total papers xy) [11].

[11] Glänzel, W. (2001), National characteristics in international scientific co-authorship relations. *Scientometrics* 51(1), 69-115

APPENDIX C
COLLABORATION PAIRS

Table 2 — *Collaboration partnerships between US states, 2011.*

Outputs included are articles, reviews and conference papers indexed in sources covered by Scopus, primarily journals, conference proceedings, book series, and trade publications. Collaboration is inferred by the pattern of co-authorship as described in the Approach and Definitions section on page 4. Co-authored publications, Salton's measure and field-weighted citation impact are for the 2011 datapoint (defined as weighted citations received in the period 2007–11 to documents published in the same period, divided by the number of documents published in 2007–11).

Most prolific pairs of collaboration states within US, 2007-2011

Rank	State 1	State 2	Publications 2007-2011	FWCI 2007-2011
1	NY	CA	27,693	3.32
2	MA	CA	25,483	3.51
3	MD	CA	20,788	3.36
4	TX	CA	18,064	3.18
5	NY	MA	18,015	3.42
6	PA	CA	16,160	3.35
7	NY	MD	14,781	3.30
8	IL	CA	14,753	3.30
9	MD	MA	14,190	3.61
10	PA	NY	13,676	3.03
11	WA	CA	12,604	3.36
12	TX	NY	11,824	3.40
13	PA	MD	11,212	3.06
14	PA	MA	10,814	3.35
15	NY	IL	10,748	3.20
16	NC	CA	10,440	3.61
17	NY	NJ	10,104	2.72
18	OH	CA	10,030	3.31
19	MI	CA	9,672	3.34
20	TX	MA	9,631	3.63

Highest international collaboration strength pairs

State 1	State 2	Publications 2007-2011	FWCI 2007-2011	Salton's measure (S)
MA	CA	25,483	3.51	0.0879
NY	CA	27,693	3.32	0.0835
MD	CA	20,788	3.36	0.0799
MD	MA	14,190	3.61	0.0758
NY	MA	18,015	3.42	0.0755
NY	NJ	10,104	2.72	0.0695
NY	MD	14,781	3.30	0.0690
PA	MD	11,212	3.06	0.0674
TX	CA	18,064	3.18	0.0656
PA	NY	13,676	3.03	0.0645
PA	CA	16,160	3.35	0.0627
IL	CA	14,753	3.30	0.0619
VA	MD	7,340	2.41	0.0618
WA	CA	12,604	3.36	0.0613
NC	MD	7,668	3.63	0.0584
PA	MA	10,814	3.35	0.0584
CO	CA	9,036	2.96	0.0571
NY	IL	10,748	3.20	0.0548
CA	AZ	7,675	2.89	0.0540
TX	MD	9,442	3.28	0.0532

Table 3 — *Top pairs of collaboration of Europe countries with countries outside Europe.*

Most prolific pairs of collaboration countries, 2007-2011

Rank	Country 1	Country 2	Publications 2007-2011	FWCI 2007-2011
1	UK	USA	84,981	2.70
2	DEU	USA	77,170	2.54
3	FRA	USA	51,476	2.63
4	ITA	USA	43,187	2.49
5	ESP	USA	30,033	2.48
6	NLD	USA	28,809	3.03
7	CHE	USA	27,368	2.93
8	UK	AUS	21,712	2.66
9	UK	CAN	20,341	3.15
10	UK	CHN	19,602	1.95
11	SWE	USA	18,381	2.86
12	ISR	USA	17,450	2.27
13	FRA	CAN	15,012	2.72
14	BEL	USA	14,221	3.11
15	DEU	CAN	14,117	3.18
16	DEU	RUS	14,024	1.71
17	DEU	CHN	13,815	2.08
18	DEU	JPN	12,444	2.39
19	UK	JPN	12,048	2.39
20	DNK	USA	11,141	3.12

Highest international collaboration strength pairs

Country 1	Country 2	Publications 2007-2011	FWCI 2007-2011	Salton's measure (S)
UK	USA	84,981	2.70	0.0697
DEU	USA	77,170	2.54	0.0654
FRA	DZA	4,621	0.84	0.0618
FRA	TUN	5,414	0.86	0.0596
UK	AUS	21,712	2.66	0.0538
FRA	USA	51,476	2.63	0.0509
MNE	MNG	42	1.48	0.0480
ITA	USA	43,187	2.49	0.0478
DNK	GRL	214	1.62	0.0475
CHE	USA	27,368	2.93	0.0473
DEU	RUS	14,024	1.71	0.0436
UK	CAN	20,341	3.15	0.0425
FRA	MAR	2,791	0.96	0.0423
NLD	USA	28,809	3.03	0.0423
ISR	USA	17,450	2.27	0.0417
ESP	MEX	5,292	1.70	0.0378
FRA	CAN	15,012	2.72	0.0378
ESP	USA	30,033	2.48	0.0361
ESP	ARG	3,920	2.01	0.0344
SWE	USA	18,381	2.86	0.0338

Table 4 — *Top pairs of collaboration of US states with countries outside US.*

Most prolific pairs of collaboration states within US, 2007-2011

Rank	State 1	Country 2	Publications 2007-2011	FWCI 2007-2011
1	WA	AUS	27,075	1.66
2	TN	IND	22,190	0.74
3	CA	UK	20,671	3.46
4	CA	DEU	20,117	3.22
5	CA	CAN	16,734	3.39
6	NY	UK	13,987	3.55
7	CA	FRA	13,862	3.33
8	CA	CHN	13,837	2.25
9	MA	UK	12,931	3.91
10	NY	CAN	12,273	3.45
11	NY	DEU	12,043	3.48
12	MA	DEU	11,650	3.70
13	CA	JPN	11,426	2.64
14	CA	ITA	10,550	3.26
15	MA	CAN	10,539	3.76
16	MD	UK	10,532	3.61
17	NY	CHN	9,997	2.10
18	NY	FRA	8,808	3.83
19	MD	DEU	8,457	3.40
20	CA	AUS	8,009	3.47

Highest international collaboration strength pairs

State 1	State 2	Publications 2007-2011	FWCI 2007-2011	Salton's measure (S)
WA	AUS	27,075	1.66	0.1643
TN	IND	22,190	0.74	0.1436
LA	CUB	2,245	0.21	0.1359
AL	GRD	177	0.40	0.0556
CA	CAN	16,734	3.39	0.0436
CA	DEU	20,117	3.22	0.0413
CA	UK	20,671	3.46	0.0410
NY	CAN	12,273	3.45	0.0389
MA	CAN	10,539	3.76	0.0382
MA	UK	12,931	3.91	0.0357
SD	ECU	103	2.84	0.0345
NY	UK	13,987	3.55	0.0338
MA	DEU	11,650	3.70	0.0333
CA	FRA	13,862	3.33	0.0332
MS	ECU	191	2.67	0.0332
CA	CHE	7,920	3.61	0.0331
RI	ECU	194	3.32	0.0326
MD	UK	10,532	3.61	0.0324
NE	ECU	189	2.67	0.0324
KS	ECU	199	2.64	0.0314

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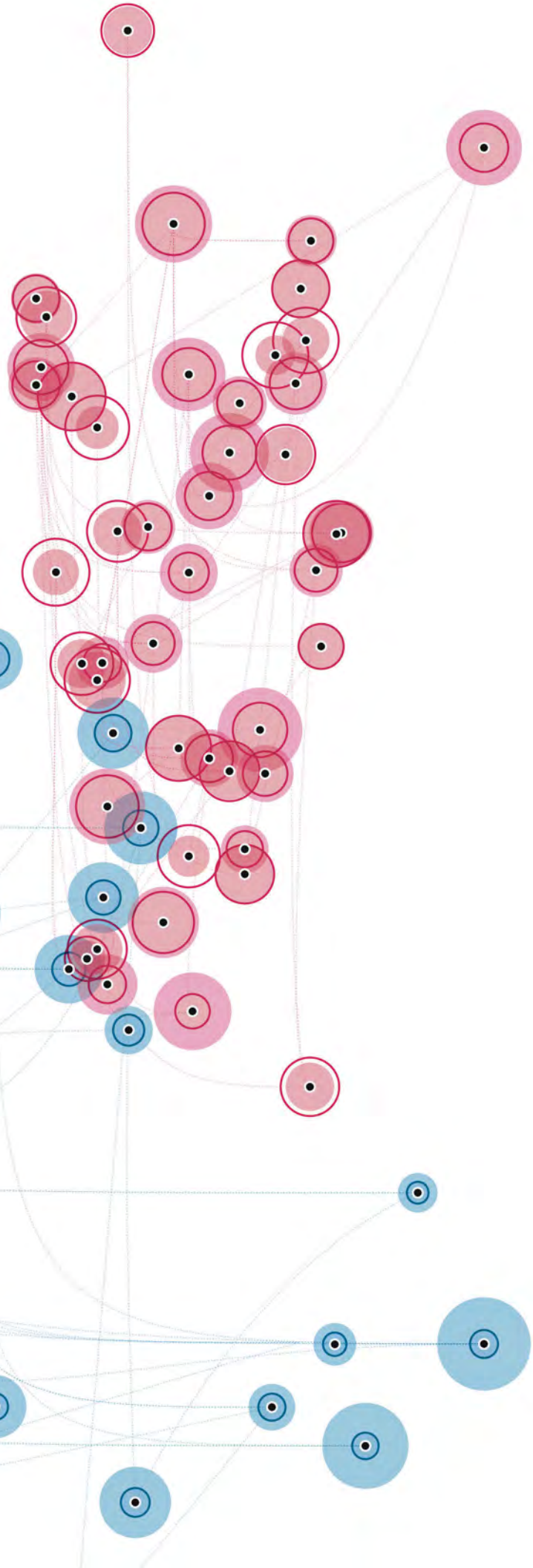

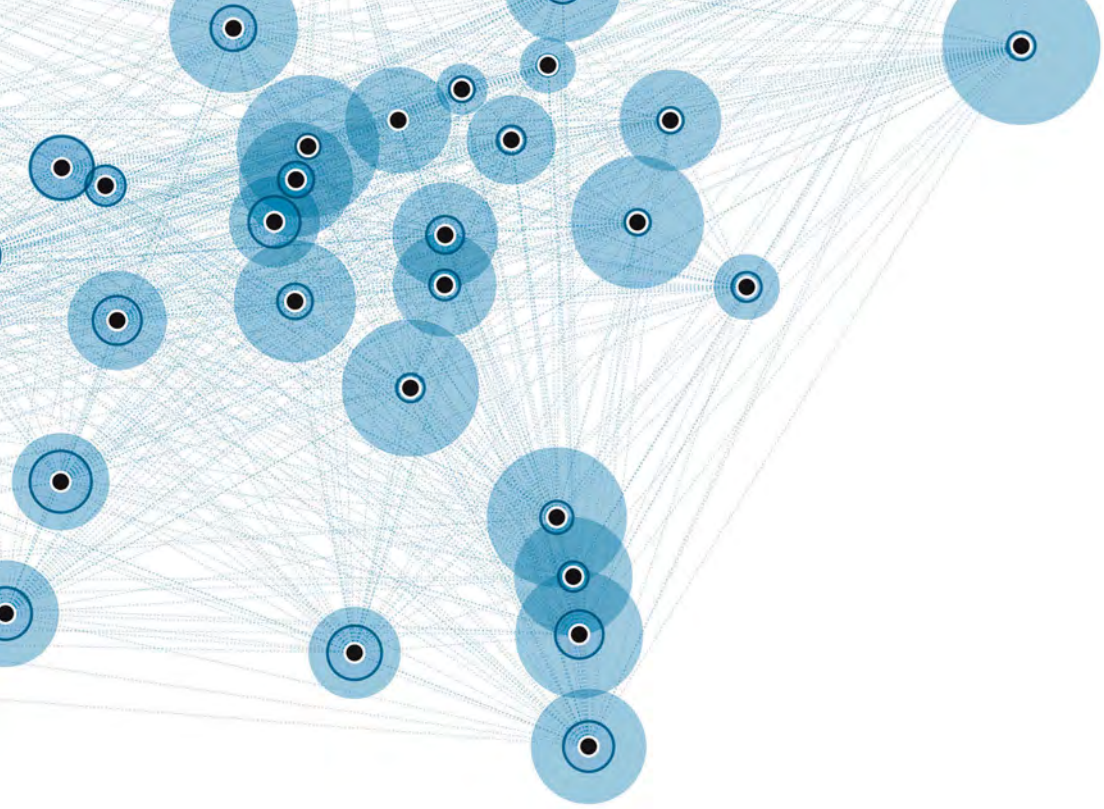

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