

A Metrics-Based Assessment of Scotland's Science Landscape 2007-2016

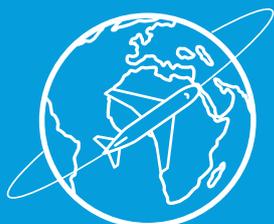
Scotland's
researchers
are
**highly
productive**



Scotland's
research
is
**high
quality**



Scotland's
researchers
are
**highly
mobile**



Scotland
is a
**global
collaborator**



The document provides highlights of the full report commissioned by the SSAC and published in January 2019 which can be found at:

<http://www.scottishscience.org.uk/publications>



The Scottish Science Advisory Council (SSAC)

provides independent advice and recommendations to inform policy development and delivery across all areas of the Scottish Government's work.

Scotland has a long-held reputation for producing excellent science, encouraging innovative thinking and building international collaborative partnerships. Its research base helps drive the economy and attracts students, researchers and academics from around the world, enriching its society.

To learn more about the relative performance of Scotland's science base, the Scottish Science Advisory Council (SSAC) commissioned Elsevier to produce a metrics-based assessment of the Scientific Research Base from 2007-2016. We have compared Scotland to the other UK nations and selected EU and non-EU countries of similar population and economic size.

This report demonstrates that the quality and productivity of Scotland's research base is impressive: Scotland produces more academic publications per researcher, and these works are cited more often by their peers, than any of the comparator nations. In 2016, Scotland had more publications in the top 1% of the most cited publications in the world than any other UK nation or EU comparator nation.

Perhaps not surprisingly, therefore, Scotland is highly successful at obtaining funding from charities, research councils, EU and global funding streams. Scotland has increased its gross expenditure on Research and Development as a share of GDP in the ten-year study period, at a higher rate than any other UK nation and comparator with the exception of Norway.

Business collaborations are also increasing in Scotland; while Business Enterprise Research and Development investment rates have been low in Scotland compared to England, this investment doubled between 2007 and 2016. It is also clear that Scottish researchers are collaborating strongly with business, and these partnerships lead to more highly cited work than elsewhere in the UK. These are among a number of achievements identified in this report that are worth celebrating.

Yet, there are results that require strategic attention. The research world is changing, with emerging research-intensive nations such as Singapore growing their capability and capacity. This has resulted in Scotland, along with other established research countries, experiencing a decrease in its share of global publications. Scotland will need to consider how it responds to the challenges in this changing landscape, as well as the inherent opportunities for building new partnerships.

In addition, a critical part of Scotland's success is the mobility of its research base, attracting world-class researchers to teach and research here. Scotland benefits more than the rest of the UK from European collaborations. But, with Brexit looming, the risk to Scottish research is therefore potentially greater than for the rest of the UK if a satisfactory post-Brexit deal for science and innovation cannot be secured in a timely manner.

The scientific research base plays a critical role in Scotland's economy and society, driving innovation and tackling today's global issues. We should all take pride in the many successes and achievements of the universities, research institutes and other bodies who contribute to Scotland's science successes. This research excellence should be nurtured, so that Scotland remains a great science and innovation nation, continuing to punch above its weight in an increasingly competitive environment.

A handwritten signature in black ink, appearing to be 'Paul Boyle', written in a cursive style.

**Professor Paul Boyle CBE FBA FRSE
SSAC Chair**

Methodology

This study compares the performance of Scotland's scientific research base with UK nations and selected EU and non-EU comparator countries, using a metrics-based assessment of scientific publications and their citations. The report builds on two previous reports in this area in 2003 and 2009 for Scotland and a series of reports by the UK Government, Department for Business, Energy and Industrial Strategy (BEIS) in 2011, 2013 and 2016. While metrics provide only one method for assessing a nation's science base, it is an objective approach which allows direct comparison between countries.

Time Period of Study

Data were collected for 2007-2016. Comparisons are made between the first five years 2007-2011 (Period 1 or P1) and the second five years 2012-2016 (Period 2 or P2).

Comparator Countries

Comparisons are made with other nations in the UK, and comparator countries in the EU and outside the EU. These were chosen based on their population, economic size and research reputations.

Selected EU Countries

Denmark (DEN), Finland (FIN), Ireland (IRL), Netherlands (NLD) and Sweden (SWE)

Selected non-EU Countries

Israel (ISR), Norway (NOR), New Zealand (NZL), Singapore (SGP) and Switzerland (CHE)

Field-Weighted Citation Impact (FWCI)

FIELD-WEIGHTED CITATION IMPACT (FWCI)



$\frac{\text{\# of citations received by a document}}{\text{expected \# of citations for similar documents}}$

Similar documents are ones in the same discipline, of the same type (e.g., articles, letter, review) and of the same age. An FWCI of 1 means that the output performs just as expected against the global average. More than 1 means that the output is more cited than expected according to the global average; for example, 1.48 means 48% more cited than expected.

Most of the analyses use data on how often a journal article is referred to, or 'cited', in other journal articles. Field Weighted Citation Impact (FWCI) takes into account the differences in research behaviour across disciplines and allows comparisons across countries and disciplines.

Mobility Definitions

Mobility was determined from the addresses recorded on publications. Researchers who had published overseas for more than two years were considered **migratory**, whilst researchers whose publication addresses were in a single country were considered to be **non-migratory**. Researchers who published overseas for less than two years before returning to their original country were deemed to be **transitory**.

Journal Classifications

Most journals can be allocated to a broad discipline. Here we follow the approach used in the 2016 BEIS Report¹, grouping journal articles into ten subject fields: Biological Sciences, Business, Clinical Sciences, Engineering, Environmental Sciences, Health and Medical Sciences, Humanities, Mathematics, Physical Sciences and Social Sciences. It is not possible to allocate some journals, such as those in *Science* and *Nature*, to single disciplines. Hence, these are classified in bibliometric analyses as 'multidisciplinary'.

Note of Thanks

The SSAC would like to thank the project steering group for their contributions to the project: Scottish Funding Council, Universities Scotland, Royal Society of Edinburgh, Highlands and Islands Enterprise, and Scottish Enterprise.

¹ <https://www.gov.uk/government/publications/performance-of-the-uk-research-base-international-comparison-2016>



Scotland's researchers are highly productive

Scotland is a very strong research performer in the UK context. In 2015, Scotland accounted for 10% of the UK researcher population and produced 12% of the UK research output. However, like other established research nations, Scotland has seen a declining share of world publications as the scientific research landscape changes, with growth in emerging research nations, such as Singapore, and large developing nations, such as India and Brazil.

- Scotland is increasing its research output, but at a slower rate than the UK and world average.
(Scotland increase 15.34%, UK 16.72%, Global 20%)
- Scotland's share of global publications continues to fall as other countries become more research active.
**(Change in average share of world publications – Percentage change from P1 to P2)
Scotland decrease of -4.2%, UK decrease of -2.9%, Singapore increase of +12.5%**
- Scotland has the highest number of publications per researcher amongst all UK nations and comparator countries (for which data was available) over the ten-year period, though Wales matched Scotland's result in 2016.
(Number of publications per researcher per total R&D Personnel (FTE) in 2016: Scotland's average is 0.53, UK average is 0.38)
- Scottish researchers are efficient, producing on average 8.54 publications per £million expenditure in 2016, ranking second out of the UK nations.
(Number of Publications per £m expenditure of UK nations in 2016 Scotland 8.54, England 4.81, Wales 9.72, Northern Ireland 4.73)

Scotland continues to invest in scientific Research and Development

- Scotland's total gross expenditure on R&D as a share of GDP is less than the UK average of 1.67% and all comparator nations, with the exception of Ireland.
(GERD as a share of GDP 2016 figures: Scotland 1.54%, UK 1.67%, Norway 2.04%, Ireland 1.18%)
- However, Scotland's increase in GERD as a share of GDP, from 1.27% in 2007 to 1.54% in 2016, was four times greater than the UK and higher than all comparators with the exception of Norway.
(Gross Expenditure on R&D as a share of GDP, % change from 2007 to 2016: Scotland increase of +21.3%, UK increase of +5.1%, Norway increase of +30.3%)
- 2016 was the first year when Business Expenditure on R&D (BERD) overtook Higher Education Expenditure on Research and Development (HERD) in Scotland. Yet, Scotland's BERD still lags behind the other UK Nations.

Table 1 – Percentage Share of BERD, HERD, GOVERD for UK nations in 2016

Country	BERD	GOVERD	HERD
Scotland	46%	7%	45.50%
England	68.70%	6.70%	22.30%
Wales	60.80%	2.10%	37.20%
Northern Ireland	74.30%	2.20%	23.50%
GBR Average	67.10%	6.60%	24.30%

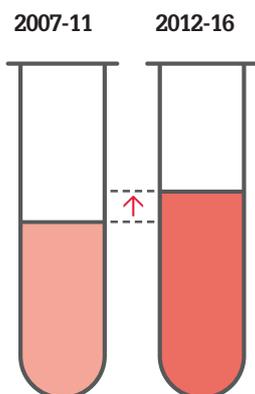
- BERD in Scotland almost doubled over the ten-year study period.
(Scottish BERD Spend: 2007 £543 million, 2016 £1072 million)
- The Top 5 Business Sectors investing in Research and Development in Scotland from 2009 to 2016 were:
 1. Miscellaneous Business Activity – Technical Testing and Analysis (£309 million).
 2. Pharmaceuticals (£164 million).
 3. Consumer Electronics (£135 million).
 4. Software Development (£72 million).
 5. Precision Instruments (£61 million).

Scotland's Science Strengths

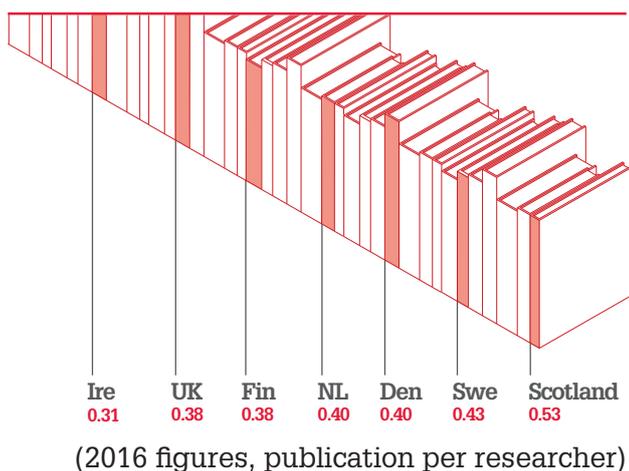
Scotland's researchers are highly productive



+15%



Scotland has increased its research output 15% between 2007-11 and 2012-16



Scotland's researchers are the most productive. Their productivity is consistently higher than the UK and all other comparator nations over the ten year period

Scotland's research is high quality



Scotland

-27%



Nearest comparator

-63%



UK average

Scotland has the highest average number of citations per researcher

27% ahead of nearest comparator country
63% ahead of the UK average (between 2007-2015)



All UK Nations



All comparators



Scotland's share of the world's top 1% most cited publications

1st of all UK nations
3rd out of all comparator countries

The Scottish Science Advisory Council commissioned a report to produce a metrics-based assessment of the Scottish Science Landscape over a ten year period 2007-2016, comparing Scotland to other UK nations and selected EU countries (Denmark, Finland, Ireland, Sweden and the Netherlands), and non-EU countries (Israel, Norway, New Zealand, Singapore, and Switzerland). These are defined as comparator nations in the graphic.

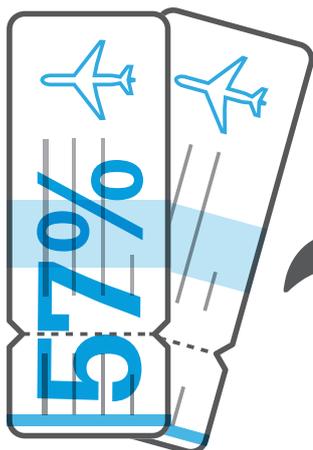
Scotland's researchers are highly mobile



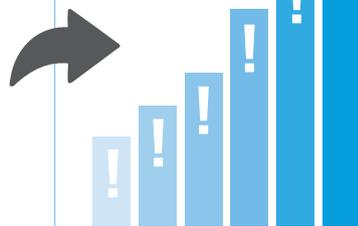
 Published outside Scotland
 Published solely in Scotland



Over 89% of Scottish researchers have published outside Scotland – compared with the UK figure of 72%



57% of Scottish researchers are transitory (spending up to 2 years abroad)



These researchers have the **highest impact** out of all UK transitory researchers

Scotland is a global collaborator



Scotland's share of joint publications with EU partners is higher than England and Wales

Scotland's international collaboration has a higher impact than the UK average

Top 5 collaborator countries

1. USA
2. Germany
3. France
4. Italy
5. Australia



↑ 33%

Academic-corporate joint publications are increasing in Scotland and have a 33% higher impact than the UK average
 Scotland's academic-corporate joint publications have increased by 14% between 2007-11 and 2012-16

Scotland's research is high quality

Scotland's research continues to be internationally recognised and respected for its quality and innovative nature.

- Scotland had the highest number of citations per researcher compared to all UK, EU and non-EU nations considered here. It was 27% higher than the nearest comparator Wales, and 63% ahead of the UK average.

(Average number of citations per researcher 2007-2016: Scotland 16.03, UK 9.81 and Wales 12.66)

- Scotland's share of the world's top 1% most cited publications, between 2007 and 2016 is 1st among all UK nations and 3rd in comparison to the EU and non-EU comparator countries.
- Academic-corporate joint publications are increasing in Scotland and have a 33% higher citation impact than the UK average.

(Field-Weighted Citation Impact (FWCI) for academic-corporate collaborations from 2007-2016: Scotland 3.51, UK 2.64).

- Scotland has the highest average Field-Weighted Citation Impact (FWCI) among all UK nations and performs well compared to other comparator countries.

Table 2 - Average FWCI per country in P1 and P2

UK Nations	P1 FWCI	P2 FWCI
Scotland	1.65	1.79
Wales	1.49	1.74
Northern Ireland	1.41	1.70
England	1.57	1.64
UK average	1.52	1.58

Non-EU Comparators	P1 FWCI	P2 FWCI
Switzerland	1.80	1.84
Singapore	1.59	1.83
Scotland	1.65	1.79
Norway	1.52	1.64
Israel	1.42	1.49
New Zealand	1.36	1.46

EU Comparators	P1 FWCI	P2 FWCI
Denmark	1.75	1.85
Scotland	1.65	1.79
Netherlands	1.75	1.78
Sweden	1.59	1.69
Finland	1.52	1.68
Ireland	1.44	1.59



Scotland's researchers are highly mobile

Scotland benefits from having an international research base as mobile researchers in Scotland are the most productive and achieve the highest research impact.

- 89% of active Scottish researchers have published at least one article under a non-Scottish institutional address, 17 percentage points higher than for the UK. *(Note – includes other UK, EU and non-EU addresses)*
- 57.1% of Scotland's research base is transitory and this researcher group has the highest productivity, producing on average 1.19 papers per researcher, and achieving the highest impact with an average FWCI of 2.25.

Table 3 – Scottish researchers', mobility, productivity and citation impact, 1996-2016

Type of Researcher	% of research base	Productivity	FWCI
Transitory	57.1	1.19	2.25
Incoming	14.3	0.84	2.12
Outgoing	17.8	0.75	1.91
Stationary	10.8	0.38	1.82

- Scotland's transitory researchers have a higher citation impact than transitory researchers elsewhere in the UK. *(Average FWCI of UK transitory researchers (1996-2016): Scotland 2.25, England 2.19, Wales 2.02, Northern Ireland 1.64)*
- Scottish transitory researchers that have been mobile within the EU have the highest overall productivity and citation impact. *(Average FWCI of Scottish transitory researchers by region of migration (1996-2016): UK 2.35, EU 2.43, non-EU 2.34)*
Productivity: in papers per researcher of Scottish transitory researchers by region of migration (1996-2016): UK 1.29, EU 1.89, non-EU 1.51)

Scotland is a global collaborator

Scotland has invested in building collaborative scientific research partnerships and networks with international partners, and the number of Scottish publications with international collaborators has risen year on year. (Note: International partners refer to those outside the UK)

- Scotland produces a higher proportion of publications with international partners than the UK average. These collaborative publications have a higher citation impact than the UK average.
(Average FWCI for international collaboration from 2007-2016: Scotland 2.17, UK 1.95)

Table 4 – Share of publications with international collaboration in Period 2

Country	Share of Publications with International Collaboration				
	2012	2013	2014	2015	2016
Scotland	48.7%	51.3%	54.2%	55.7%	56.9%
UK	47.0%	48.8%	51.5%	53.6%	56.0%

- Compared to EU and non-EU nations, Scotland is third behind Denmark and Wales for average citation impact arising from international collaborations over the ten-year study period (2007-2016).
(Average FWCI for International Collaborations (2007-16): Scotland 2.18, Wales 2.19, Denmark 2.23)
- Scotland's share of joint publications with EU partners is considerably higher than that of England, and second only to that of Northern Ireland within the UK.

Table 5 – Average share of publications with EU collaboration in P1 and P2 for UK nations

Country	Share of Publications with International Collaboration	
	Period 1	Period 2
Scotland	55.3%	56.3%
England	51.4%	52.7%
Wales	50.1%	53.6%
Northern Ireland	58.4%	58.2%

- Scotland's citation impact arising from EU collaborations has increased during the study period and is second among UK nations to Wales.

Table 6 – Average FWCI for UK-EU collaboration for P1 and P2

Country	FWCI	
	Period 1	Period 2
Scotland	2.38	2.67
England	2.24	2.29
Wales	2.29	2.91
Northern Ireland	1.97	2.56

- Scotland collaborated most with the USA (16,983 joint publications), Germany (10,631 joint publications), France (7,526 joint publications), Italy (6,819 joint publications) and Australia (6,477 joint publications) during 2007-2016.

Subject Science Strengths

Analysis was carried out on ten subject areas in more detail: Biological Sciences, Business, Clinical Sciences, Engineering, Environmental Sciences, Health and Medical Sciences, Humanities, Mathematics, Physical Sciences and Social Sciences.

Highlights include:

- Publications in Physical Sciences account for the largest share of Scottish publications, followed by Clinical Sciences and Biological Sciences.
(Share of Scotland's Publications per Subject in 2016: 1st Physical Sciences with 35.7%, 2nd Clinical Sciences with 32.5%, 3rd Biological Sciences with 25.3%)
- Scotland's citation and publication impact is above the world average with an FWCI of more than 1 in every subject area while Clinical Sciences leads with an average FWCI of 2.14 in P2.
- The subject area that experienced the highest relative increase in total publications and citation impact over the ten-year period was the Humanities.

Table 7- Top three subject areas increasing their publication output during the study period

Top 3 Subject Areas increasing their citation impact (FWCI) from P1 to P2		Top 3 Subject Areas increasing their publication output from P1 to P2	
1st	Humanities increase 15.8%	1st	Humanities increase 37.8%
2nd	Biological Sciences increase 12.2%	2nd	Environmental Sciences increase 25.5%
3rd	Social Sciences increase 10.8%	3rd	Clinical Sciences increase 24.9%

- Scotland is the only country among all UK, EU and non-EU comparator countries to increase its share of publications in Physical Sciences.

Table 8 – Change in the share of publications in Physical Sciences per country, from P1 to P2

UK	Change in share of Physical Sciences	EU Comparators	Change in share of Physical Sciences	non-EU comparators	Change in share of Physical Sciences
Scotland	+1.1%	Denmark	-5.4%	Switzerland	-5.2%
Great Britain	-2.4%	Finland	-2.7%	Israel	-3.6%
England	-2.6%	Ireland	-8.4%	Norway	-4.4%
Wales	-3.2%	Netherlands	-9.0%	New Zealand	-2.5%
Northern Ireland	-8.5%	Sweden	-0.8%	Singapore	-3.5%



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scottishscience@gov.scot