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Dynamics of scientific production in the world, in Europe and in France, 2000-2016

Science and Technology Observatory

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Contents

Summary

This report sets out to analyse the dynamics of scientific output since the year 2000, depicting global trends and comparing the trajectories of the European Union, the USA and China. It goes into more detailed analyses for the countries which account for the largest share of scientific publications and international prizes. It takes a disciplinary perspective on world publications and provides an in-depth analysis of the case of mathematics.

Within this global context, the report offers a focus on France, which is systematically compared with a set of nine benchmark countries. French data are analysed more thoroughly than in the bibliometric reports published by the European Union, the OECD and certain countries.

Overall, the report both updates results found in previous analyses of world scientific production and explores a number of specific issues. Dealing with national comparisons, it complements international university rankings.

Country size, economic and scientific outputs

Global economic powers are also scientific powers, as they invest most heavily in academic research and produce the most publications. However, when ranked using qualitative indicators such as output per capita, scientific impact of publications, or number of Nobel Prize winners per researcher, their positions are quite diverse.

France provides an illustration of the different perspectives offered by size-dependent and size-independent indicators. By the mid-2010s France was the world's 6th largest economy, and ranked 26th in terms of per capita output (GDP). It ranked 6th in volume of public research expenditure, and 18th for its share of national output. In 2016, France was the world's 8th largest contributor to world scientific publications and ranked 12th for the intensity of top 1% most highly-cited publications in its total output.

Evolution of world scientific publications since 2000

Since the turn of the millennium, the annual number of scientific publications has been multiplied by 2.3, reaching 1.9 million in 2016. This increase can be attributed to a combination of factors: an increase in the number of publications by the journals and proceedings already indexed in 2000, but more importantly the inclusion of new journals and conference proceedings in the Web of Science database, used as the primary source of the OST database.

Three research-intensive countries maintained their rank in terms of contribution to world scientific publications between 2000 and 2016: the USA (1), the UK (3) and Germany (4). China moved up from 8th to 2nd and India from 12th to 6th. South Korea moved up from 14th to 9th and Iran from 20th to 16th. Meanwhile, Japan dropped from 2nd to 5th, France from 5th to 8th and Canada from 6th to 10th. The number of publications produced by Russia changed very little until the early 2010s, and over the period Russia has slipped from 9th to 14th.

At the global level, the number of co-publications was multiplied by 3.1 between 2000 and 2016, while the number of international co-publications was multiplied by 3.6. International co-publications thus increased from 15% of total publication output in 2000 to 25% in 2016. The long-term trend for collaborative research between institutions is still going strong, at both the national and international levels. The number of authors per publication varies from one discipline to the next, but also within disciplines, depending on the average size of research teams working in different fields. For a given discipline, it also varies somewhat by country.

Impact of scientific publications for the major publishing countries

Of the 20 largest producers of scientific publications, Switzerland is the country with the highest impact, with a number of citations per publication one-third greater than the world average. Other countries producing modest volumes of publications also show strong performances, such as the Netherlands, Australia and Denmark. The average impact of American publications is 30% higher than the world average, while the impact of Chinese publications is 15% lower (0.85). The average impact of Chinese publications is slightly lower than that of South Korea and slightly above that of Iran. It has overtaken the impact of Japanese publications, which is decreasing.

Country distribution and international mobility of Nobel laureates

The geographical distribution of the 179 recipients of scientific Nobel Prizes awarded between 1994 and 2017 is analysed on the basis of their affiliation at three key dates: when they received their doctoral degree, when they did the work which earned them the prize, and when the prize was awarded. Over the period, only 10% of laureates were still at their *alma mater* and around a quarter had worked in at least two different countries. Japanese laureates tend to remain in Japan, or to move between Japan and the USA. French laureates are among the most settled.

Holders of doctorates from American universities won the greatest number of Nobel Prizes, and many laureates from other countries moved to American universities later in their academic careers. Over 50% of future Nobel laureates received their doctoral degrees from American institutions, 58% did their Nobel-winning work in America, and almost two-thirds of recipients were based at American institutions when the prize was awarded. These percentages far exceed the American share of highly-cited publications, with 37% in the top 1%. The same is true of the UK, Japan, France, Germany and Russia. China, Canada and Australia, on the contrary, have a higher share of highly-cited publications than of Nobel laureates.

Scientific performance of the European Union

In 2012-14, the EU produced nearly 30% of world scientific publications, ahead of the United States (21%) and China (15%). The US however remains the leader in the production of top 1% most highly-cited publications (33% versus 30% for the EU). It also has a higher intensity of top 10% and top 1% most highly-cited publications in its scientific production. The US share of Nobel Prize winners is higher than that of the EU, and it is more attractive as these laureates move from one institution to another during their career.

Evolution of the disciplinary distribution of world publications

The disciplinary distribution of the world's scientific publications has changed considerably, largely thanks to the rapid rise of China and the focus of its research efforts in particular in chemistry and engineering. Medical research remains the discipline with the most publications, but fundamental biology was overtaken by chemistry in 2005 and by engineering in 2012. In 2016 chemistry was the second most-published discipline, with engineering in third. The number of engineering publications surpassed that of physics in 2009. Applied biology-ecology now produces a number of publications comparable with that of earth sciences-astronomy-astrophysics and the social sciences, since growth has been stronger in these disciplines. In 2000, social sciences and humanities produced an equivalent volume of publications, but the progress of the social sciences has been noticeably greater since the turn of the century. In 2000, computer science had the smallest number of publications, but during the period it passed the humanities and mathematics.

Mathematics is analysed in detail and illustrates the scientific profile and performance of some countries. Among the main producers of publications in mathematics, China stands out for its rapid growth: the annual volume of Chinese publications has outstripped that of Germany since 2002, France since 2003 and the USA since 2012. In 2016, China's world share was 19.3%, compared with 15.8 % for the USA and 5.3% for France, the third largest publisher in mathematics, ahead of Germany in fourth.

Within the discipline, the two pre-eminent fields of research are Fundamental mathematics (44%) and Applied mathematics (36%). Fundamental mathematics accounts for more than half of total output in Russia, Japan and Israel; in France the figure is 49%. In China, Applied mathematics accounts for almost half of total output in the discipline.

Among the countries considered in the analysis of this discipline, Belgium, the USA, the UK, Austria and Italy have an average number of citations per publication 20% above the world average; Germany, France and the Netherlands an impact index 10% above the world average. Publications from the USA, the UK and Canada have an impact greater than the world average in the four research fields of the discipline. France's best performance is in Fundamental mathematics, with an impact index 15% above the world average.

France's scientific profile and performance compared

In 2016, France remains highly specialised in mathematics: the proportion of mathematics as a share of its total publications is 70% higher than the world average. It is also specialised in physics, earth sciences-astronomy-astrophysics and computer science, with a share of these disciplines in its output 20% above the world average. The share of medical research and fundamental biology in French publications is just above the world average, while the share of applied biology-ecology is just below. Since 2000, the humanities' share of French publications has fluctuated between 80% and 100% of the world average; in engineering it has hovered between 80 and 90%. The share of social sciences is 40% below the world average, but since the turn of the century France has become specialised in economics, along with Germany, Italy and Spain.

Overall, France's scientific profile is quite different from that of the countries selected to form the France benchmark group: Germany, Italy, Japan, the Netherlands, South Korea, Spain, Sweden, the United Kingdom and the United States.

The respective performances of countries in terms of the scientific impact also vary considerably. Besides, the average impact of a country's publications may conceal similar levels of performance in different disciplines, as is the case in the USA (with an average impact of 1.3 and a 1.2 - 1.6 range), or quite disparate performances, as in France (with an average of 1.1 and a 0.6 - 1.4 range).

The scientific position of France within the European Union

Within the EU, the relative positions of the top 10 contributors to scientific publications have changed. The UK remains the largest contributor, but its number of publications is now only just greater than the total for Germany, which has seen more dynamic growth. Italy has seen much more rapid growth in number of publications than France, just edging past France in 2016.

France intensity of top 10% most highly-cited publications is just below the EU average at 4% above the world average. It has improved its performance since 2000, but to a lesser extent than some other European countries, including Sweden, Spain, Italy and Belgium.

French scientific co-publications and their impact, by partner country

The USA is the most frequent partner of French international co-publications, but the scientific affinity between the two countries is moderate (0.6). The scientific affinity index with a partner is the ratio of that partner's share in French international co-publications to its share in total international co-publications. Russia, for example, is not a major partner of France but has a scientific affinity index 14% greater than the neutral value (1). Three of France's main partners have a scientific affinity index greater than 1: Belgium, Italy and Switzerland. The affinity indices for France's two major European partners, Germany and the UK, are close to 1. Among France's main partners, China has the lowest scientific affinity index (0.4).

For all the countries in the France benchmark group, the impact of international co-publications is greater than that of co-publications between domestic institutions, but the size of the gap varies from partner to partner. Co-publications between EU partners, which are most frequent, have an average impact below that of co-publications with the USA.

The impact of French international co-publications varies considerably from one discipline to the next. In mathematics, it is slightly greater than the impact of domestic co-publications. The gap is much larger in medical research and the humanities, where the share of international co-publications is quite low.

Reader's guide

A glossary can be found in Annex 6. Asterisks are used to mark the first occurrence in the text of a term found in the glossary.

ISO country codes for the world's 40 top producers of scientific publications

Country	ISO code
Argentina	ARG
Australia	AUS
Austria	AUT
Belgium	BEL
Brazil	BRA
Canada	CAN
Switzerland	CHE
China	CHN
Czech Republic	CZE
Germany	DEU
Denmark	DNK
Egypt	EGY
Spain	ESP
Finland	FIN
France	FRA
United Kingdom	GBR
Greece	GRC
India	IND
Ireland	IRL
Iran	IRN

Country	ISO code
Israel	ISR
Italy	ITA
Japan	JPN
South Korea	KOR
Mexico	MEX
Malaysia	MYS
Netherlands	NLD
Norway	NOR
New Zealand	NZL
Poland	POL
Portugal	PRT
Romania	ROM
Russia	RUS
Singapore	SGP
Sweden	SWE
Thailand	THA
Turkey	TUR
Taiwan	TWN
United States	USA
South Africa	ZAF

The rest of the world is abbreviated as RoW.

Abbreviations used for names of academic disciplines

Major disciplines	Abbreviations
Applied biology-Ecology	App. Bio.-Eco.
Fundamental biology	Fund. Bio
Chemistry	Chemistry
Computer science	Comp. Sc.
Mathematics	Maths
Physics	Physics
Medical research	Medical R.
Engineering	Engineering
Earth sciences-Astronomy-Astrophysics	Earth Sc., Astro.
Humanities	Humanities
Social sciences	Soc. Sc.

Abbreviations used for different fields of research in mathematics

Research field	Abbreviation
Applied mathematics	A. Maths
Mathematics, interdisciplinary applications	Maths IA
Fundamental Mathematics	F. Maths
Statistics & Probability	Stat. & Proba.

When the text refers to a field of research in mathematics the latter is capitalised.

Introduction

Since the turn of the millennium, innovation has been acknowledged by high income countries not only as an essential factor in their economic development, but also as a major element of their response to societal challenges, such as environmental changes and population ageing. Public policies aimed at promoting innovation have proliferated, backed by more and more resources and deploying an ever-growing arsenal of instruments to cover the activities and factors which contribute to innovation.

Analyses of innovation systems have also evolved, with a better understanding of the contribution of scientific research to innovation. Scientific research generates new knowledge which, after a lapse of time that may run into decades, provides the basis for major innovations and stimulates the development of entirely new economic activities. Research by public institutions and private companies is also essential to develop capacities to absorb* new knowledge and to generate incremental innovation in various fields. Last but not least, through interaction with the higher education sector, research contributes to developing the skills and creativity of the hugely diverse array of individuals who work within contemporary innovation systems.

Various empirical studies in economics of science and innovation have demonstrated that the quality of research is key to maximising its economic and social impact. There is a positive correlation between the quality of research results and those variables essential to its capitalisation, such as the involvement of researchers in collaboration with firms or commercialisation activities (patents, start ups). In this respect, the scientific excellence and socio-economic impact of research complement one another (Bornmann 2017, Ellegaard & Wallin 2015, Wilsdon et al. 2015).

In this context, national governments and those international organisations charged with improving public policies in these areas often seek to compare country performances in terms of research and innovation. National and international reports deal with the factors that may contribute to innovation. The OECD and the European Commission regularly publish indicators focusing on innovation factors (OECD 2016, 2017, EU 2016, 2018). UNESCO publishes reports on scientific activity, containing indicators for a broader set of countries (UNESCO 2015). France recently published a report seeking to position the country's innovation capacity with reference to a group of benchmark countries (DGRI-DGE 2016). Some countries publish reports focusing more closely on the resources and performance of scientific research. The USA publishes a science and technology report every other year (NSF 2016, 2018). In Europe, the United Kingdom, Germany, Sweden and Switzerland regularly or periodically publish indicators benchmarking their research systems (BEIS 2017, Helmich et al. 2018, Monaco et al. 2016, SEFRI 2018). France's position in terms of research and publications is addressed in some of these reports in a highly aggregated manner, using a limited number of indicators and with no mention of the evolution over time. The bibliometric indicators published by the European Union (Campbell et al. 2013) and the OECD (2016) provide useful information regarding France's position in the first decade of the 21st century, including at the level of disciplines and global challenges.

The present report provides a detailed analysis of France's scientific position since year 2000 in the global context. It can be considered as a companion to university rankings based on research performance, particularly the Leiden and Shanghai rankings (ARWU 2018, CWTS 2018). Focusing on the national level, this report encompasses all publications by all entities involved in research activities in France, regardless of status or size. Emphasis is placed on comparisons with other countries, and it does not go into the level of individual public and private institutions. This report also complements rankings based on composite innovation indicators (EU 2017, Cornell University et al. 2018).

The report is divided into four chapters followed by a series of annexes focusing on data sources, methodology and terminology (the latter in the form of a glossary[1]).

1. Asterisks are used to mark the first occurrence in the text of a term found in the glossary.

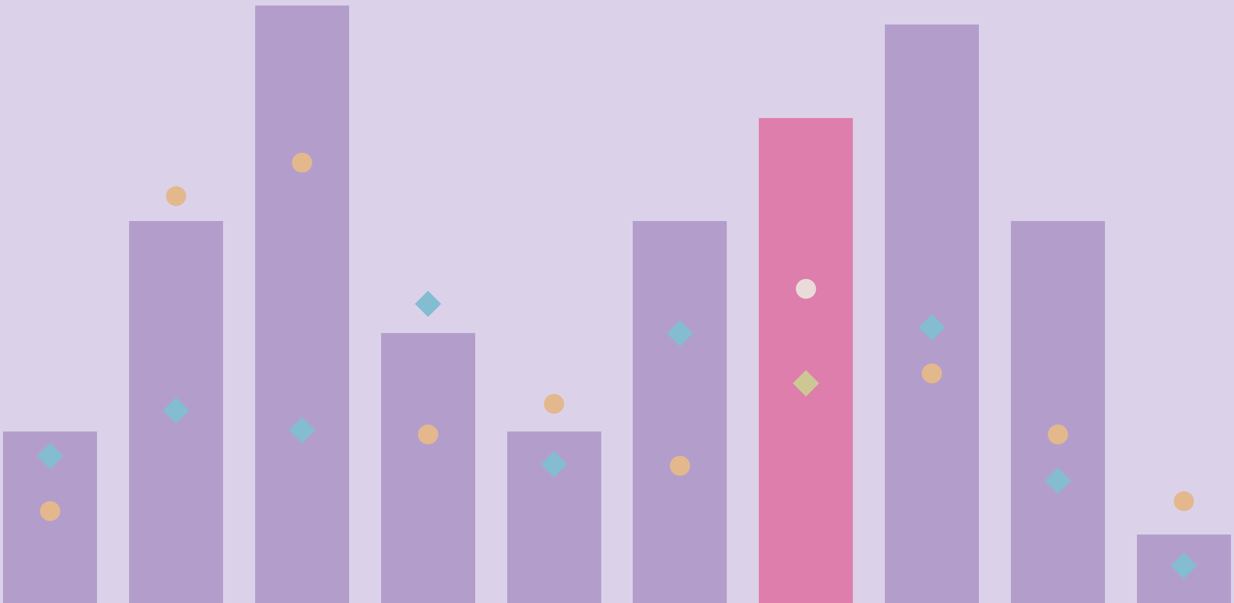
The first chapter contains statistics which are used to compare the position of a dozen countries with reference to different types of demographic, economic, technological and scientific variables. It also provides details of the types of indicators used in this report, emphasising the distinction between those which are dependent on the size or economic weight of a country and those which aim to reflect the quality or intensity of scientific activities or output.

The second chapter looks at various facets of scientific output in the world since the turn of the millennium. It contains systematic indicators for the world's 20 largest producers of scientific output, along with specific details for a number of emerging nations. It highlights the rise of domestic and international co-publications and the impact* of these co-publications. These bibliometric indicators are backed up by an analysis of the international mobility of Nobel Prize winners over the course of their careers. This chapter also compares the trajectories of the European Union, the USA and China, using both bibliometric indicators and data on the Nobel laureates.

Chapter 3 analyses the evolution of the distribution of publications by discipline since the year 2000. It discusses the impact of China's growth on this disciplinary distribution. It also provides a detailed analysis of the case of mathematics. In order to obtain different perspectives on the discipline, two corpora of publications are analysed in turn. The first contains those journals identified in the OST classification as belonging to the discipline of mathematics, in keeping with chapter 2. The second corpus comprises articles published in the most prestigious journals as identified by the Australian Mathematical Society.

Chapter 4 focuses on the case of France, which is systematically compared with a set of nine countries. The France benchmark group* includes Germany, Italy, Japan, the Netherlands, South Korea, Spain, Sweden, the United Kingdom and the United States. This chapter details France's scientific profile and performance. It includes an exploration of France's position in the social sciences and humanities disciplines. It also discusses France international co-publications, including the propensity to co-publish by partner country and discipline.

1 General benchmark statistics and choice of indicators



This first section proposes a number of statistical reference points in order to situate countries in relation to one another, going beyond their output of scientific publications. These indicators serve as a reminder of the importance of distinguishing between volume indicators and intensity indicators when making international comparisons. The former can be used to compare the relative weight of countries for different variables, while the latter serve to compare the intensity or quality of a variable.

Table 1 compares countries using both types of indicators. Population is a key variable when determining the size of a country, and its output. The world's two most populous nations, China and India, have similar demographic weights (18%), while the population of the third most populous, the United States, is four times smaller. But the situation is very different in terms of their relative economic weight. In dollars at the official exchange rate, the United States remains the leading power with 24% of total world output, compared with 15% for China and 5% for India. However, when the exchange rate takes into account the fact that services cost less in relative terms in emerging nations[2], China's economic weight is equivalent to that of the United States and India's share of world output rises to 7%. France accounts for 0.9% of the world's population, 3.3% of output in dollars and 2.4% at purchasing power parity (PPP*).

Those countries with the largest populations or economies are not necessarily the most productive. The USA is ranked 10th for per capita output, while Germany is 16th and France 26th. The biggest emerging

Table 1. Size-dependent and size-independent demographic, economic and scientific indicators for a selection of countries, 2016

	United States		China		Japan		Germany		United Kingdom	
World share or size - independent indicator[a]	Value	World rank	Value	World rank	Value	World rank	Value	World rank	Valeur	World rank
Demographics										
Share of world population (%)	4.3	3	18.5	1	1.7	10	1.1	16	0.9	22
Gross domestic product (GDP)										
Share of world GDP ($,%)	24.5	1	14.7	2	6.5	3	4.6	4	3.5	5
Share of world GDP (PPP,%)	15.4	2	17.7	1	4.4	4	3.3	5	2.3	9
GDP / capita (PPP, 000 $)	**57.6**	**10**	**15.5**	**75**	**42.3**	**25**	**48.9**	**16**	**42.7**	**24**
Gross domestic expenditures on R&D (GERD) of non-profit organizations (NPO)										
Share of world NPO-GERD* (PPP, %)	25.4	1	17.5	2	6.1	4	6.5	3	2.7	8
NPO-GERD / GDP (%)	**0.79**	**13**	**0.47**	**39**	**0.67**	**18**	**0.94**	**6**	**0.56**	**29**
Scientific publications										
Share of publications	19.3	1	17.7	2	4.0	5	4.6	4	4.6	3
Share of citations within 3 years*	26.4	1	14.5	2	3.3	7	5.2	4	6.0	3
Share of highly-cited publications (top 1%)	33.4	1	14.2	2	2.0	11	5.4	4	6.9	3
Field normalised Impact[c]	**1.3**	**3**	**0.9**	**16**	**0.8**	**20**	**1.1**	**10**	**1.3**	**5**
Proportion of publications in the top1% most highly cited*	**1.6**	**2**	**0.9**	**13**	**0.5**	**20**	**1.1**	**8**	**1.5**	**4**
Nobel Prizes[d]										
Share of Nobel laureates, 1994-2017	58.4	1	0.6	12	6.7	3	3.6	5	11.5	2
Nobel laureates 1994-2017 / 100,000 researchers	**9.3**	**1**	**0.1**	**17**	**1.9**	**15**	**2.2**	**14**	**8.4**	**2**

a. Lines corresponding to size independent indicators are highlighted in purple.
b. Most recent year: 2015.
c. Field normalised impact (FNI) for 2014 publications; ranks for countries with more than 10,000 publications.
d. Physics, chemistry and medicine/physiology (see section 2.3.3 for methodology).

2. At purchasing power parity (PPP*).

nations, as well as Russia, are much further down the table for this indicator. The small nations of Northern Europe, on the other hand, enjoy high per capita outputs. A similar contrast between volume indicators and intensity indicators can be found in the scientific domain.

The USA is the country which devotes the most resources to academic research, measured in Table 1 as expenditure on non-profit R&D (NPO GERD). In this ranking, China comes in second, with Germany third and Japan fourth. But ranks are very different for the intensity of resources allocated to academic research, i.e. spending on research as a share of national output (NPO GERD/GDP): the United States comes in 13th position, Japan in 18th and China in 39th. France, the country with the world's 6th largest budget for academic research, sits in 12th position for its share of national output. For this indicator, South Korea is in 5th position and Germany in 6th. As a share of national output, France's investment in research is slightly higher than that of the United States (0.82% and 0.79% respectively), while German investment is identical to that of South Korea (0.94%). The intensity of resources allocated to academic research is around half as high in China and India, but considerably higher in Northern Europe. In the three countries with the highest values for intensity of academic research, Denmark, Sweden and Finland, spending exceeds 0.95% of GDP[3]. In Switzerland, Austria and the Netherlands it is close to 0.90%.

France		India		Italy		Canada		South Korea		Russia		Netherlands		Sweden	
Value	World rank	Value	World rank	Value	World rank	Value	World rank	Value	World rank	Value	World rank	Value	World rank	Value	World rank
0.9	21	17.8	2	0.8	23	0.5	38	0.7	27	1.9	9	0.2	65	0.1	89
3.2	6	3.0	7	2.4	8	2.0	10	1.9	11	1.7	12	1.0	18	0.7	22
2.3	10	7.2	3	1.9	11	1.3	17	1.6	14	3.0	6	0.7	27	0.4	39
41.4	**26**	**6.6**	**121**	**38.4**	**28**	**44.8**	**21**	**36.6**	**32**	**24.8**	**53**	**50.5**	**13**	**48.9**	**17**
3.9	6	4.9	5	2.1	11	2.2	10	3.0	7	2.6	9	1.3	16	0.8	20
0.82	**12**	**0.35[b]**	**49**	**0.54**	**33**	**0.79**	**14**	**0.94**	**5**	**0.45**	**42**	**0.88**	**10**	**0.99**	**1**
3.1	8	3.6	6	3.1	7	2.7	10	2.9	9	2.2	14	1.5	17	1.0	21
3.4	5	2.5	12	3.4	6	3.3	8	2.6	11	0.8	23	2.0	13	1.2	18
3.0	7	1.5	14	2.9	8	3.3	6	1.9	12	0.3	26	2.1	10	1.1	16
1.0	**12**	**0.7**	**21**	**1.1**	**11**	**1.1**	**9**	**0.9**	**17**	**0.4**	**28**	**1.3**	**2**	**1.2**	**8**
0.9	**12**	**0.4**	**22**	**0.9**	**11**	**1.1**	**9**	**0.7**	**19**	**0.2**	**28**	**1.4**	**6**	**1.1**	**10**
4.5	4	0.0	-	0.0	-	1.1	10	0.0	-	1.7	8	1.7	8	1.1	10
3.8	**9**	**0.0**	**-**	**0.0**	**-**	**1.5**	**15**	**0.0**	**-**	**0.6**	**16**	**5.6**	**7**	**3.8**	**8**

www.hceres.fr/OSTReport2019-Tab-1

Sources: World Bank, UNESCO, Web of Science, OST treatment

3. Figures that are not in table 1 originate from the same data sources.

Generally speaking, the richest countries invest intensively in academic research, although disparities exist within this group. Italy and the United Kingdom, for example, have relatively weak intensities in academic research (0.6% of GDP).

In terms of research results, the volume and quality indicators give contrasting international rankings. In 2016, the United States, China and the United Kingdom were the top three contributors to world publications, and highly-cited publications. France was the 8th largest contributor[4], behind India, Japan, Germany and Italy, but came in 5th in terms of impact, ahead of India and Japan. The impact of publications is measured by the number of citations per publication, normalised with the world average citation per publication in the same year and the same field. The USA ranks third in the world in terms of impact, while China is way down in 16th place. Germany is ranked 10th and France 12th, with an impact index similar to that of Italy. The top places in terms of impact are occupied by European countries, including Denmark, the Netherlands and the United Kingdom.

As with publications and citations, the USA leads the world in terms of Nobel Prize winners over the past quarter of a century. China's position is radically different, since only one Chinese researcher has become a Nobel laureate, winning the prize for medicine in 2015. The fact that China's share of Nobel Prizes falls far below its share of world publications may be attributed to the fact that China has only recently established itself as a scientific powerhouse. The quality of China's scientific output is improving, but since Nobel Prizes are often awarded to researchers of a certain age, China does not yet have a sufficiently large pool of distinguished candidates. South Korea, which has yet to receive a Nobel Prize, is at a disadvantage given the small size of the country's population. The second most successful country in terms of Nobel Prize winners since 1994 is the United Kingdom, followed by Japan and then France.

The situation is very different if another intensity indicator is considered: number of Nobel Prizes per researcher (table 1, last row). The United States and the United Kingdom retain the top 2 spots based on this indicator. However, a number of smaller countries with just a handful of laureates also perform very strongly by this measure: Norway, Israel, Switzerland, the Netherlands and Sweden are ranked 3rd to 5th and 7th and 8th respectively. France comes in 9th place.

Table 1 demonstrates how indicators of weight depend on the size of a country, in terms of its demographic, economic or scientific variables. Intensity or quality indicators, on the other hand, are not dependent on a country's size. Table 2 presents the major indicators used in this report into two categories. Definitions can be found in the Methodology annex and in the Glossary.

Table 2. Main indicators used in the report for countries and disciplines, by type

Size-dependent indicators	Size-independent indicators
Number of publications	Rate of co-publications or international co-publications, as a percentage of total publications
World share of publications	Number of authors per publication
World share of highly-cited publications	Specialisation index for a discipline or research field
Number or share of international scientific prizes	Field normalised impact of publications
	Activity indicator in a citation class (e.g. top 1% of most highly-cited publications)

4. The ranking are given for fractional counts of publications (see glossary).

2 World scientific publications and international mobility of Nobel laureates

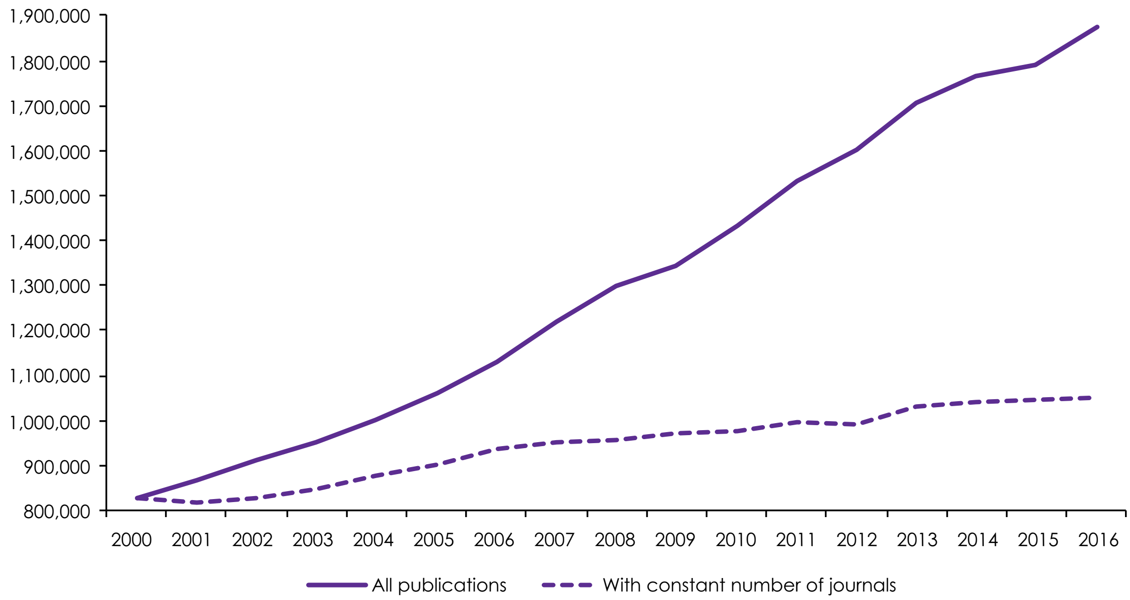
Since the start of the 21st century, the volume of scientific publications has more than doubled and the ranking of the world's top 20 producers has been shaken up. In addition to the sheer volume of output, various emerging nations have made great strides forward in terms of quality. The disciplinary distribution of scientific publications has also changed considerably. The proportion of co-publications has continued to grow, and the number of authors has become very high in certain disciplines. These global trends are analysed using a series of bibliometric indicators, which serve to categorise the output of scientific publications by country and by major discipline. The impact of the formidable growth of Chinese publications on the profile and performance of other countries is explored by constructing a counterfactual world without China. Specific issues are also documented, like the impact of international co-publications according to the partner country.

Bibliometric indicators are supplemented by an analysis of the geographical distribution of Nobel laureates and their international mobility.

2.1. Growth in the number of publications in the world since 2000

Since the turn of the millennium the annual number of publications in the world has more than doubled, reaching 1.9 million in 2016. Figure 1 shows that the number of publications appearing in journals or conference proceedings already included in the database in 2000 has increased by 27%, reaching just over one million by 2016. These existing sources have thus tended to publish a larger number of articles*. But the bulk of the increase in the number of world publications can be attributed to the expansion of the corpus, with the addition of new journals and proceedings to the Web of Science database.

Figure 1. Number of world scientific publications: total and with constant journal set, 2000-2016

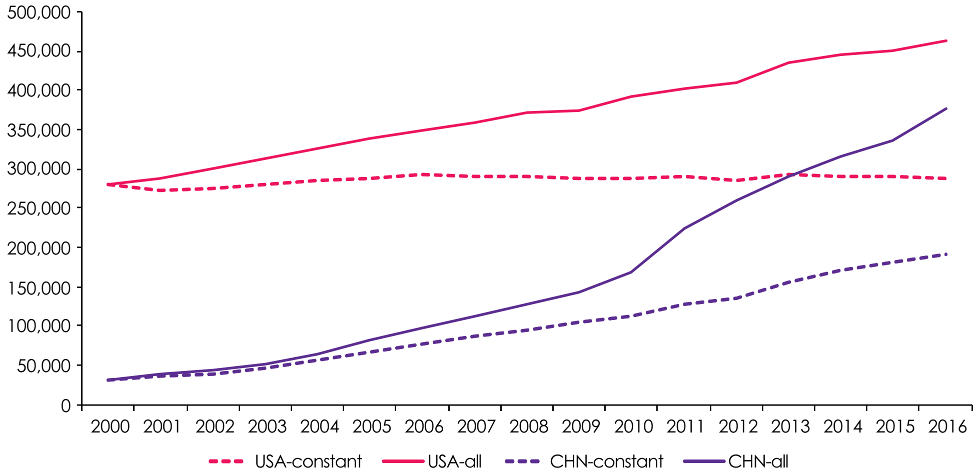


www.hceres.fr/OSTReport2019-Fig-1 *Source: Computed by OST using WoS*

The inclusion of these new sources corresponds to two distinct trends. Firstly, the Web of Science has been incorporating existing journals after a process of selection, with a view to offering a more comprehensive overview of world scientific output. German, Spanish or Chinese journals for example have been added to the database, to better reflect the output of national research communities. Secondly, new journals have been founded in response to the emergence of scientific fields. The same process applies to papers published in conference proceedings, which are treated as articles. As a result, the database included almost 10,000 journals in 2007, 12,600 in 2012 and 13,700 in 2016.

At the national level, tracking the evolution of publications in established and newer journals yields similar results for the United States and European countries (Figures 2a and 2b). The number of publications in existing journals has increased by 3% in the United States, 5% in the United Kingdom, almost 10% in France and 11% in Germany. Over the same period, the total number of publications has risen by between 70% (United States, United Kingdom, France) and 80% (Germany). The overall increase can thus largely be attributed to the inclusion of new journals in the database.

Figure 2a. Scientific publications[a]: total number and with constant journal set, United States and China, 2000-16

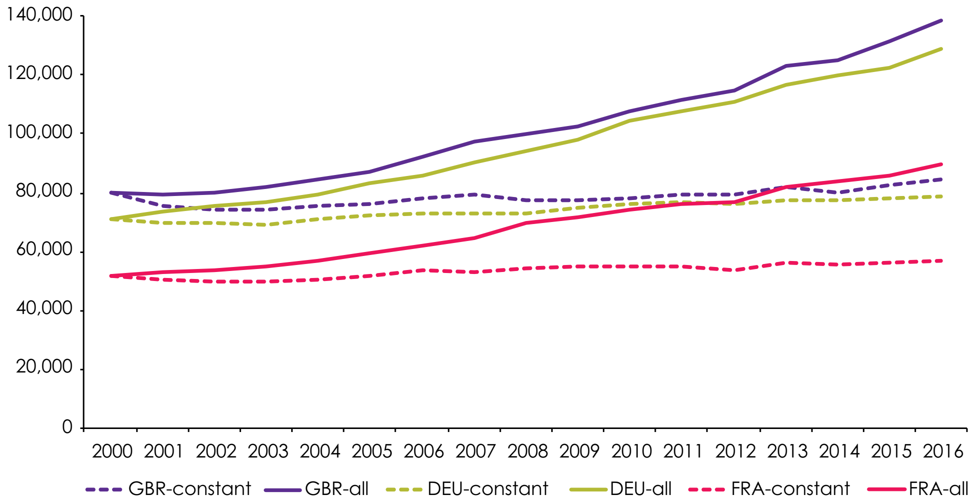


a. Whole count*

www.hceres.fr/OSTReport2019-Fig-2a

Source: Computed by OST using WoS

Figure 2b. Scientific publications[a]: total number and with constant journal set, Germany, France and United Kingdom, 2000-16



a. Whole count

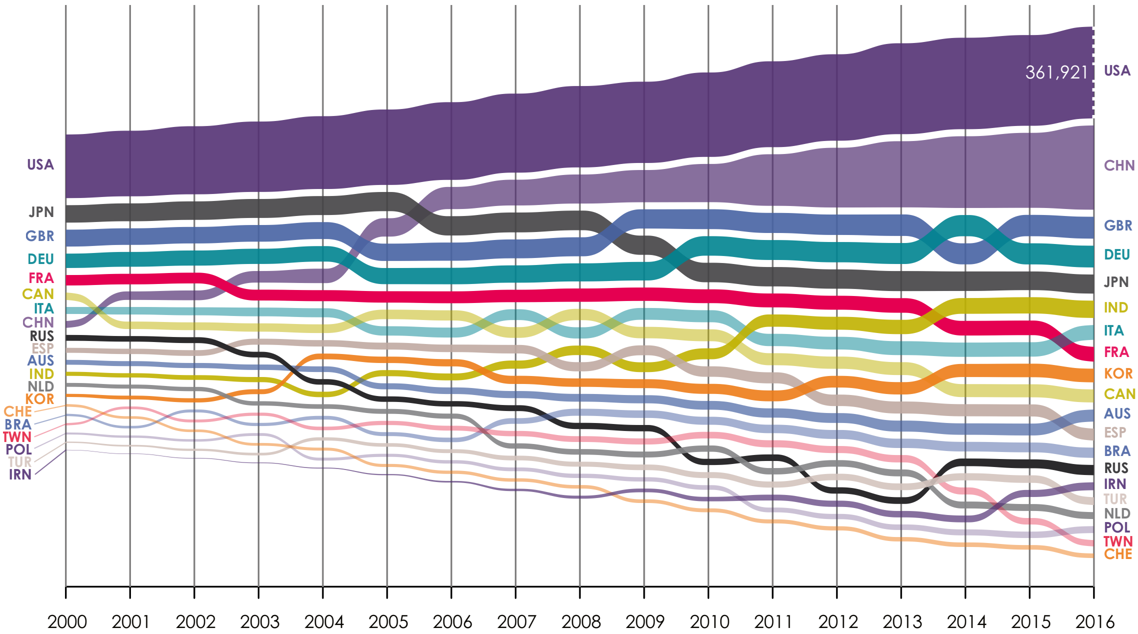
www.hceres.fr/OSTReport2019-Fig-2b

Source: Computed by OST using WoS

The contrast is particularly sharp with China. While the total number of Chinese publications has increased twelvefold over this period, the number of publications in journals that already existed in 2000 has increased six-fold. About half of the rise in the number of publications can be attributed to contributions to journals and conference proceedings already present in the database in 2000. Researchers in China have succeeded in publishing their work in established journals, thus overcoming the dual handicap of being based in a non-English-speaking and emerging country[5]. Since the mid-2000s, Chinese researchers have become much more inclined to publish in English (Wang 2016). International co-publications have provided one access route to international journals, although generally not the most prestigious[6]. Figure 2a shows that since 2010 the number of Chinese publications has increased sharply as a result of the integration of new journals in the database, including from China.

Figure 3 shows that the number of publications originating in the top 20 producers also increased considerably between 2000 and 2016. All countries saw growth over this period but trajectories varied greatly from one country to the next, with consequences for their respective positions.

Figure 3. Trends in scientific publications, top 20 countries, 2000-16



www.hceres.fr/OSTReport2019-Fig-3 *Source: Computed by OST using WoS*

Since the turn of the millennium, three historically research-intensive nations have maintained their rank: the United States (1), the United Kingdom (3) and Germany (4). Some emerging nations have seen a massive surge in their scientific output, rising towards the top of the world table in terms of number of publications. The stand-out example is China, which has progressed from 8th in the world to 2nd. Actually, in 2016, China and the USA have produced a similar number of publications (Figure 3)[7]. India has witnessed a similar evolution as China, moving up from 12th to 6th. South Korea and Iran have moved up from 13th to 9th and 20th to 15th respectively.

Symmetrically, and despite the increase in their volume of publications, a number of research-intensive countries have been overtaken by emerging countries. Chinese scientific output overtook that of Italy and Canada in 2001, then France in 2003, Germany and the United Kingdom in 2005 and Japan in 2006. Indian output has grown more gradually since 2005, overtaking Spain (2010), Canada and Italy (2011) and finally France (2014). Over the same period, Japan has slipped from 2nd to 5th place and Canada from 6th to 10th. France has moved from 5th to 8th; the volume of Italian publications being slightly higher in 2016. Despite solid growth in its number of publications, Spain has slipped from 10th to 12th, behind Australia in 2016. In 2000 the world's 20th-largest producer of academic publications was Iran. In 2016 it was Switzerland, having dropped five places since 2000 while Iran had moved up five.

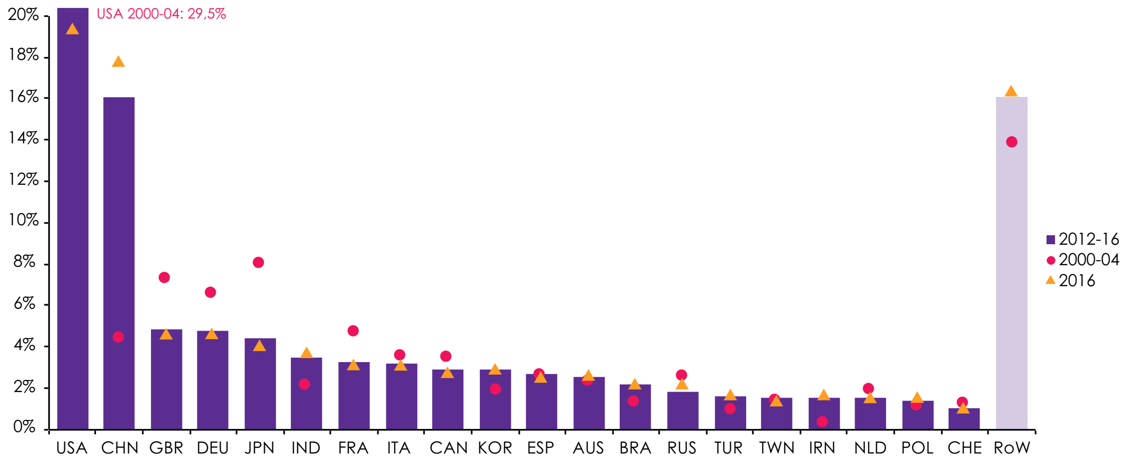
Russia is a somewhat unique case. The number of Russian publications grew very little between 2000 and the early 2010s, and the country slipped from 9th in the world to 17th by 2013. Since then, a surge in output has seen Russia move back up to 14th place, overtaking Turkey and the Netherlands.

5. The publication schedule of journals may also play a role – for example, biannual journals going quarterly.
6. For physics, see Zhou & Lv (2015) and for mathematics, Zhou & Tian (2014).
7. Based on Elsevier's Scopus database, which includes more journals from China than WoS, the statistics compiled by the National Science Foundation indicate that China has overtaken the US in terms of the number of publications in 2016 (fractional count, NSF 2018).

Figure 4a offers another angle on the evolving distribution of world scientific publications. Between the early 2000s and the early 2010s, the respective shares of the United States and China moved much closer together, standing at 19% and 18% in 2016[8]. Box 1 details the impact of the rise of China on the share of various countries. This is indicative of a broader phenomenon of convergence between research-intensive nations on the one hand and emerging nations on the other. The shake-up of the research output rankings shown in Figure 3 corresponds to a shift in global shares. The top 20 producers now account for a smaller part of total global output, with publications from the rest of the world rising from 14% at the start of the century to 16% in 2016.

Figure 4b shows that countries producing between 1% and 0.5% of the world's scientific publications have also experienced contrasted dynamics. The share of historically research-intensive small European countries such as Sweden and Belgium is on a decreasing trend. On the contrary, catching-up European countries such as Greece and Romania, as well as emerging countries from Asia (Malaysia), Latin America (Mexico) and Africa (South Africa) are increasing their global share.

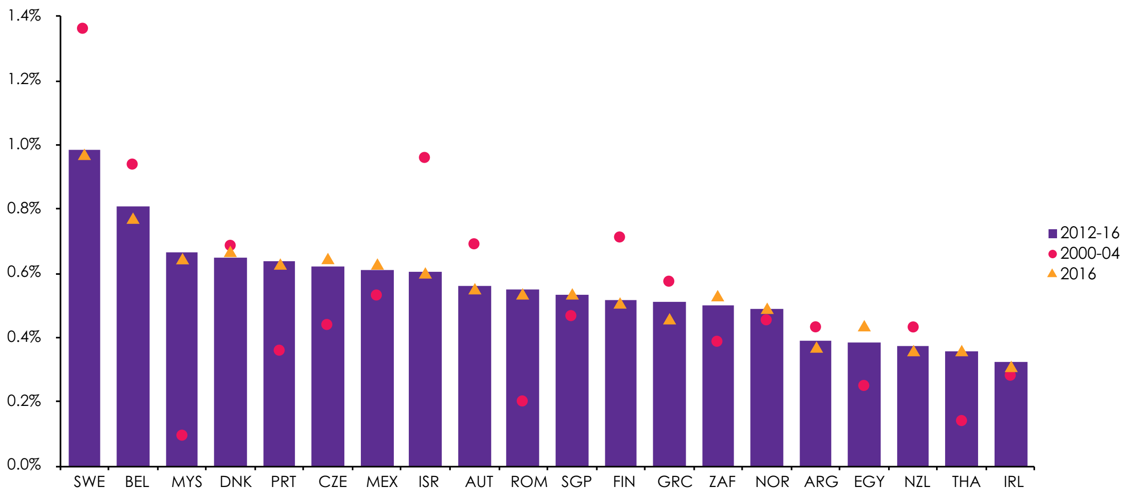
Figure 4a. World share of scientific publications, top 20 countries, 2000-16



www.hceres.fr/OSTReport2019-Fig-4a

Source: Computed by OST using WoS

Figure 4b. World share of scientific publications, countries ranked 21st to 40th, 2000-16



www.hceres.fr/OSTReport2019-Fig-4b

Source: Computed by OST using WoS

All in all, Figures 4a and 4b demonstrate that the world's scientific publications are becoming less geographically concentrated, thanks to the developing scientific capacities of emerging countries and, more generally, countries catching up to the historic leaders, including certain European nations.

8. Again, according to the Scopus database, China has a slightly larger share than USA (NSF 2018).

Box 1. The effects of China's rise on bibliometric indicators
1. Share of world publications

In order to assess what impact the increase in Chinese publications has had on classical bibliometric measures, we simulated a scientific world without China defined by all global scientific publications minus Chinese ones. All publications affiliated with at least one address in China were excluded from our bibliometric database. This corpus was used to calculate different indicators and the values for this counterfactual world without China were compared with the actual values, emphasizing the implications of the rise in Chinese publications on other countries.

Figures B1a and B1b show the difference between various countries' actual shares of world publications and what those shares would look like in a world without China (in % points). The USA is the country whose share has been hit hardest by the upturn in Chinese publications, with the impact rising from 1 percentage point in 2000 to 3.7 points in 2016. The reduction in European shares caused by the rise in Chinese publications varies considerably from one country to the next. In 2016, the impact ranges from 0.2 points for Sweden to 1 point for Germany (Figure B1b). The difference was 0.7 points for France in 2016. These disparities can be partly explained by the varying intensity of co-publication with China.

Figure B1a. Difference between share of world publications with and without China, 2000-16: USA, % points

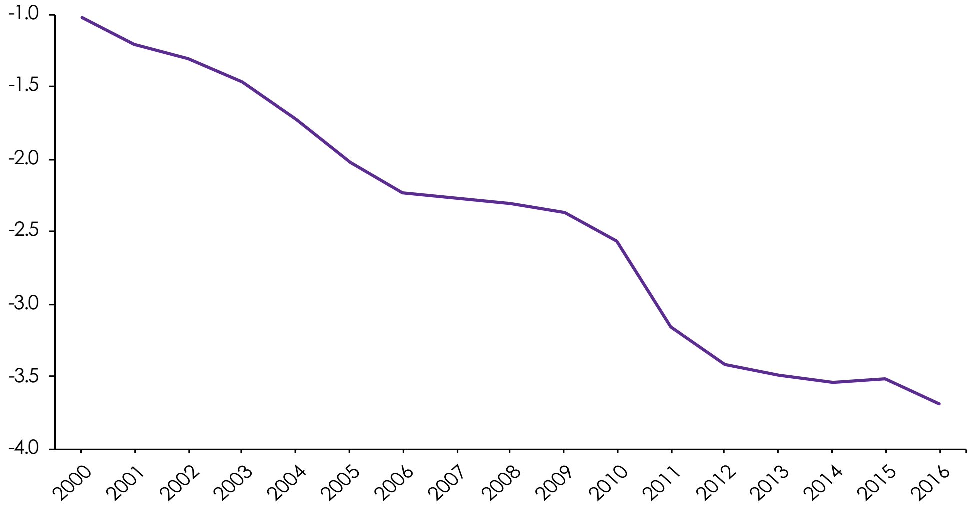
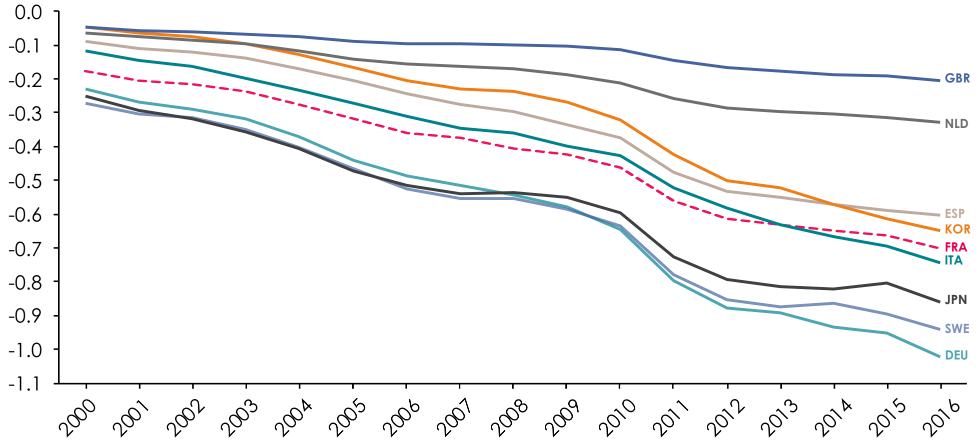


Figure B1b. Difference between share of world publications with and without China, 2000-16: various countries, % points



www.hceres.fr/OSTReport2019-Fig-B1a

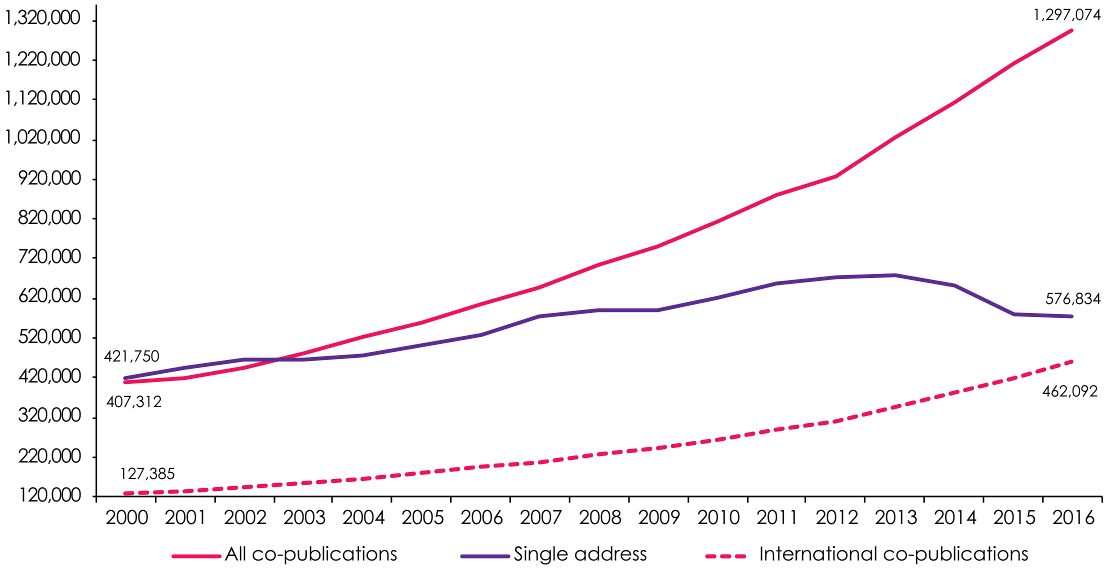
www.hceres.fr/OSTReport2019-Fig-B1b

Source: Computed by OST using WoS

2.2. Domestic and international co-publications

At the global level, the number of co-publications involving multiple institutions is growing much more rapidly than the number of publications affiliated with a single institution (Figure 5). The latter grew slowly throughout the 2000s, before levelling off and going into decline in 2013. Conversely, between 2000 and 2016 the number of co-publications more than tripled and the number of international co-publications virtually quadrupled. The share of international co-publications grew from 15% in 2000 to 25% in 2016[9]. The long-term trend for collaborative research involving multiple institutions thus continues apace, at both national (Jones et al. 2008) and international levels (Narin & Whitlow 1990, Winkler et al. 2015, Jonkers & Wagner 2017, OECD 2017).

Figure 5. Trends in domestic and international co-publications, 2000-16



www.hceres.fr/OSTReport2019-Fig-5 *Source: Computed by OST using WoS*

The trend for co-publication is on the rise in all disciplines, but the average number of authors per publication varies considerably from one discipline to the next. Table 3 shows that the highest average number of authors is in physics, and especially particle physics, with a global mean of 7.6 and 37.1 respectively in the period 2012-16. This can be explained by the importance of large-scale scientific infrastructure in this discipline, particularly its experimental branch (Pritychenko, 2016). The organisation of access to these facilities also plays a role. As such, the number of authors is much higher in European nations such as France or the United Kingdom than it is for the United States. International collaboration at CERN[10] has boosted the number of co-publications with multiple authors. These hyper-collaborations can yield publications for which the list of authors runs into the thousands.

At the global level, the average number of authors per paper is close to 6 in medical research, fundamental biology and astronomy (Table 3). Here again, the figure tends to be higher in Europe, particularly in earth sciences-astronomy-astrophysics. The average number of authors in the other fields of life and materials sciences is between 3 and 5. France tends to have a higher number of authors than the world average and the average for countries shown in Table 3, except Russia. This is particularly true in medical research and fundamental biology, where the average number of authors is the highest for France (8.2).

9. Calculated using the data from Figures 1 and 5.
10. CERN : European Organization for Nuclear Research.

Table 3. Average number of authors per publication, by discipline, 2000-04 and 2012-16

	World		USA		CHN		FRA		RUS		GBR	
Disciplines	2000-04	2012-16	2000-04	2012-16	2000-04	2012-16	2000-04	2012-16	2000-04	2012-16	2000-04	2012-16
Physics	4.5	7.6	6.5	19.5	7.9	17.9	10.0	52.6	10.8	54.7	11.3	55.1
Particle physics	*7.9*	*37.1*	*16.6*	*125.8*	*25.7*	*272.2*	*31.1*	*358.1*	*29.4*	*324.2*	*38.2*	*287.6*
General physics	*5.9*	*10.2*	*15.1*	*39.0*	*13.9*	*29.3*	*21.9*	*92.0*	*23.7*	*76.7*	*26.9*	*93.8*
Nuclear physics	*5.7*	*13.7*	*8.3*	*41.0*	*8.5*	*47.2*	*12.6*	*93.2*	*11.1*	*76.0*	*13.7*	*103.3*
Earth sciences, astro.	3.5	5.8	3.8	10.1	4.3	10.4	5.0	23.7	4.1	38.0	4.3	19.3
Medical research	4.6	5.8	4.4	5.8	5.1	6.9	5.7	8.2	4.8	7.2	4.2	6.3
Fundamental biology	4.4	5.7	4.3	5.8	5.0	7.0	5.6	7.9	4.5	6.3	4.6	6.9
Applied Biology-Ecology	3.4	4.6	3.4	4.6	4.1	5.9	4.3	6.4	3.1	4.5	3.6	5.6
Chemistry	3.8	4.7	3.6	4.8	4.3	5.1	4.5	5.8	4.0	4.7	3.9	5.3
Engineering	3.2	3.8	3.2	3.9	3.6	4.1	4.3	4.9	4.5	4.3	3.3	4.2
Social Sciences	2.3	3.1	2.2	3.2	2.9	3.1	3.3	4.3	2.3	3.0	2.1	3.2
Computer science	2.7	3.4	2.7	3.6	3.0	3.7	2.9	3.9	2.4	3.0	2.7	3.8
Humanities	2.0	2.5	1.9	2.6	2.6	3.7	2.2	3.1	2.3	2.6	1.8	2.5
Mathematics	2.0	2.4	2.1	2.5	2.1	2.7	2.0	2.5	1.8	2.0	2.2	2.6
All disciplines	3.3	4.5	3.5	6.0	4.1	6.4	4.5	11.2	4.1	11.8	4.0	10.4

www.hceres.fr/OSTReport2019-Tab-3

Source: Computed by OST using WoS

The humanities, social sciences and mathematics have a smaller average number of authors, between 2 and 3. Once again, in the social sciences and humanities the average number of authors tends to be higher in France, although on a lesser scale. In mathematics, on the other hand, the French average is in line with the world average.

2.3. Scientific impact and attractiveness of the world's largest producers of publications

It has often been noted, at the institutional, national and international levels, that the statistical distribution of citations of scientific publications is highly asymmetric. Some publications are never cited, while a small proportion of publications account for a large share of citations[11]. A similar scenario emerges when the statistics by author are analysed rather than by individual publication. A recent study contains just such an analysis looking at the first decade of this century (Turner et al. 2016). For the period 2000-10, this study identifies over 13 million scientific publications from 9.5 million distinct authors. In that time two million authors[12], i.e. 22% of the total, produced 3.5 million publications which received no citations within the 4-year period corresponding to the study's citation window* (see the methodological annex). In the same period, 261,000 authors, i.e. less than 3% of the total, produced 80% of the top 10% most-cited publications.

11. After five years it is close to 20% in medical sciences and close to 30% in natural sciences. It then decreases with time. See De Solla Price (1976), Sugimoto and Larivière (2018).

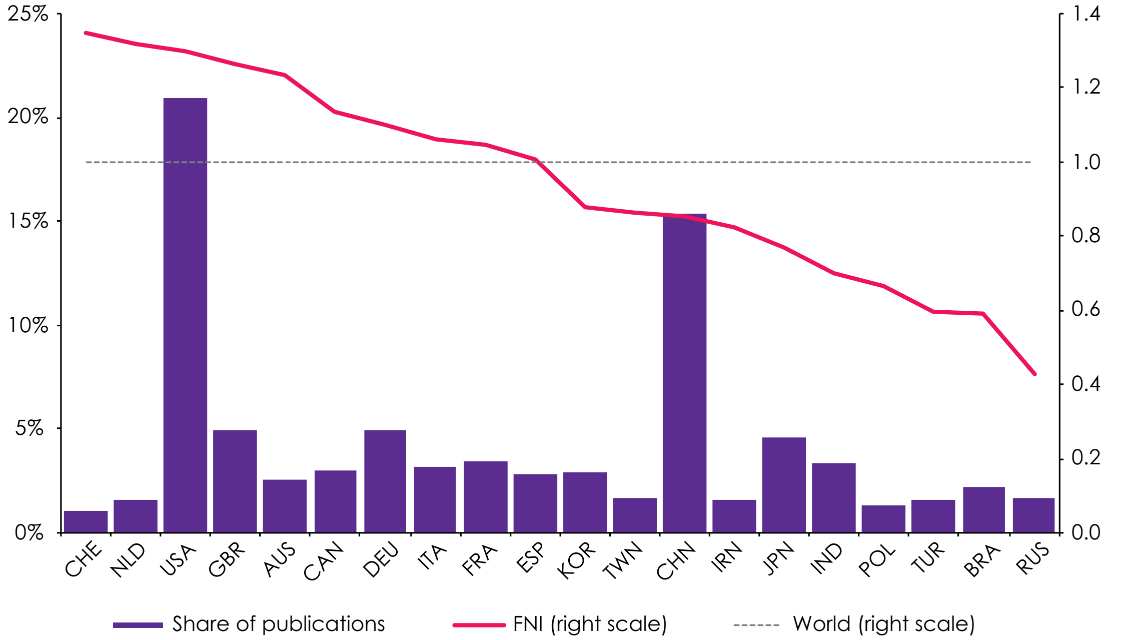
12. This study uses the Scopus bibliometric database.*

The asymmetric distribution of citations makes it necessary for comparisons between countries to combine indicators measuring the average scientific impact of publications with indicators measuring each country's capacity to produce highly-cited publications. Strong representation in the ranks of highly-cited publications is considered as an indicator of scientific excellence.

2.3.1. Average impact of publications from the leading producers

Average impact of publications is measured using the field normalised impact (FNI). The normalisation procedure consists in dividing each publication citation rate by the average citation rate of all publications in the same research field during the same year. Figure 6 shows the impact of publications from the world's 20 leading producers in 2014. This impact is measured using a 3-year citation window. Countries appear in descending order of FNI, serving as a reminder that impact is not dependent on the volume of a country's publications.

Figure 6. World share of publications and impact: 20 largest producing countries, 2012-14



www.hceres.fr/OSTReport2019-Fig-6

Source: Computed by OST using WoS

Among the world's top 20 producers, Switzerland has the highest relative number of citations per publication with an FNI of 1.32. Other countries producing modest volumes of publications perform strongly in terms of scientific impact, including the Netherlands, Australia and Denmark. The United States, as the world's largest publisher, has an impact 30% above the world average, whereas China, the second largest producer, has an impact 15% below the world average. The average impact of Chinese publications is on a par with that of Taiwanese publications, slightly below the average for South Korea and just above Iran. In 2014 the average impact of Chinese publications (0.85) overtook that of Japanese publications (0.77), which has been in decline for a number of years.

Box 2. The effects of China's rise on bibliometric indicators
2. Scientific impact of publications

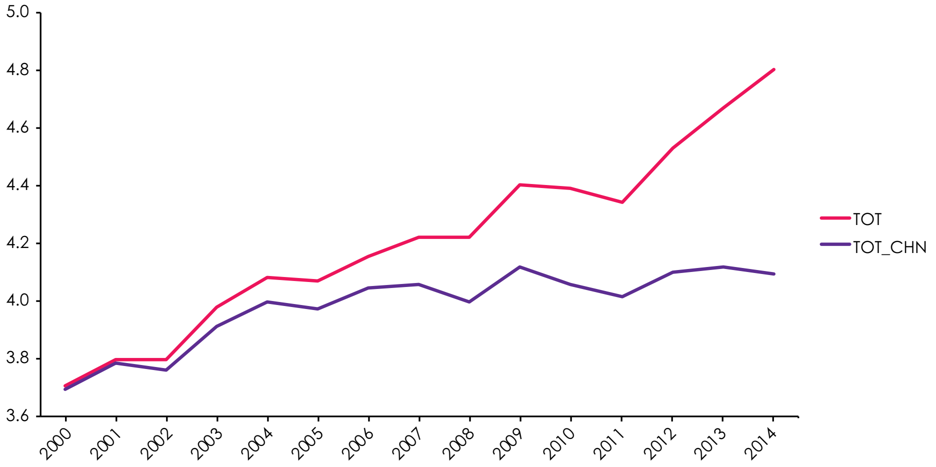
The simulation of a world without China (see Box 1) allows to better appreciate the growing influence of Chinese publications on the impact indicators. This simulated perimeter excludes not only those publications emanating from addresses in China, but also the citations associated with them. This hypothetical world without China thus includes neither citations in Chinese publications, nor citations of Chinese publications.

Figure B2a shows that in a world without China (TOT_CHN), which has fewer publications and fewer citations, the average number of citations per publication is lower. This reduction cannot be attributed to the discounting of all Chinese publications since, while their impact has increased since 2000, it remains below the world average (0.85 for 2012-14, Figure 6). Two channels are involved.

The first is international co-publications involving China. These bilateral or multilateral co-publications are not counted in our world without China, but some of them receive a number of citations above the world average. In this model they are completely discounted, whereas when calculating the indicators for the whole world they are counted on a fractional basis for the partner countries involved. As such, if a publication is co-signed by an American university and a Chinese university then each country receives 50% of the credit. In the world without China, the 50% which would have been added to the American total also disappears.

Secondly, the fall in the average number of citations in a world without China is also due to the fact that reducing the total volume of publications reduces the number of opportunities for citation, and of course the fact that references contained in Chinese publications are discounted. And, as it happens, Chinese publications cite publications from other countries, and tend to contain abundant references to publications from the leading scientific countries (Stahlschmidt and Hinze 2018).

Figure B2a. Number of citations per publication, world average with and without China



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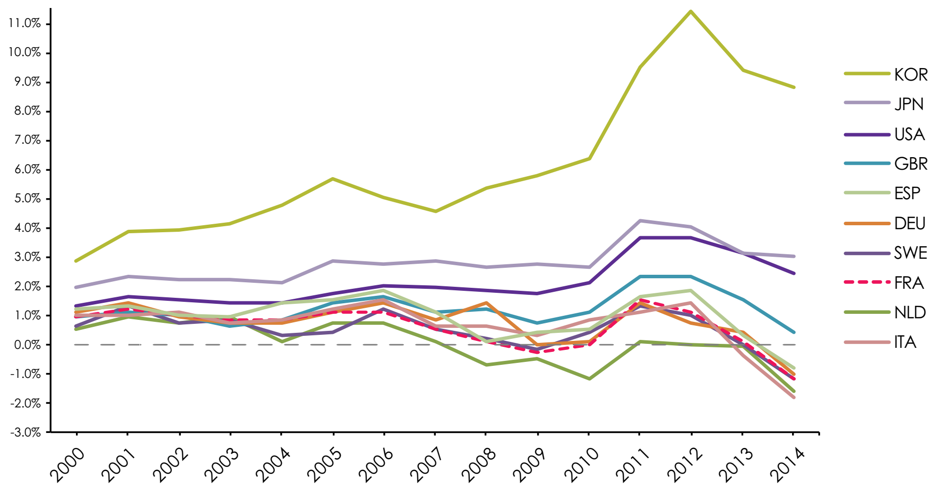
Source: Computed by OST using WoS

Figure B2b. Impact of publications: FNI in actual world minus FNI in world without China, selected countries



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Source: Computed by OST using WoS

In a world without China, the average number of citations per publication for all countries is modified *via* two channels, operating at the international level: co-publications with China and citations in Chinese publications. In theory, the consequences for a country's publication impact should thus depend on the intensity of that country's scientific interactions with China. Partnerships with China and citations in Chinese publications make a certain contribution to the scientific impact of the countries included here. The disparity is most apparent for those countries which collaborate extensively with China, and grows over time. Between 2000 and 2014 the impact of Korean publications would have fallen by almost 6% in a world without China, while the USA would have seen a 2.5% reduction. The effect on countries such as France, Germany and the Netherlands would be less substantial. The gap tends to decrease after 2012 and becomes negative for a number of European countries at the end of the period. Since those countries co-publish relatively little with China, this evolution should be attributed to changes in the citation behaviour of Chinese researchers.

The simulation has been generated for other countries with similar results, depending largely on their level of collaboration with China.

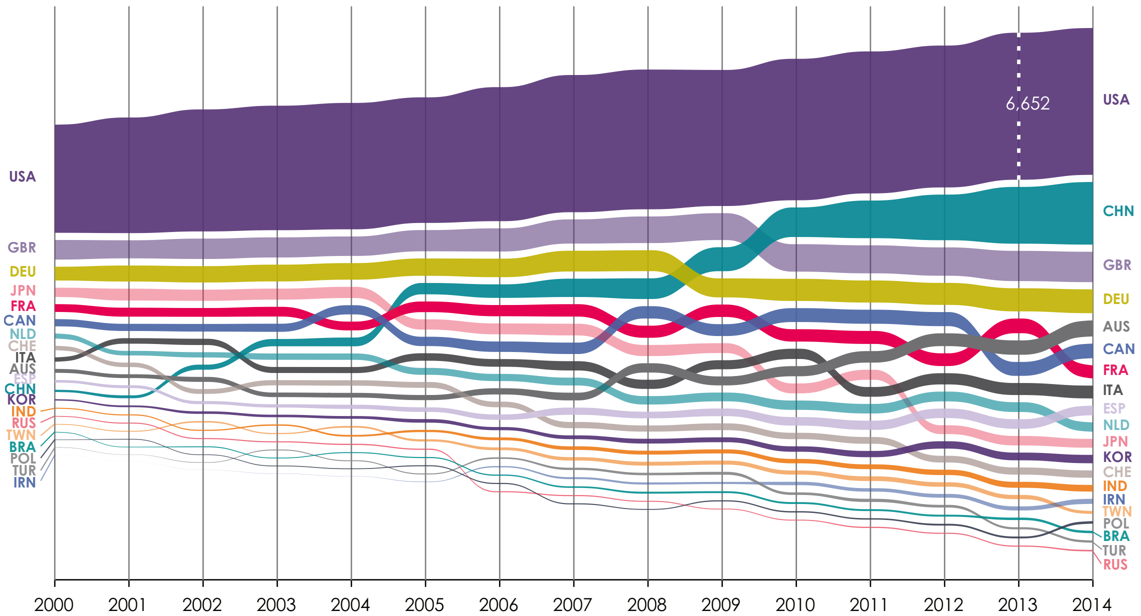
2.3.2. Highly-cited publications: volume and intensity of output

The most highly-cited publications are used to construct bibliometric indicators designed to measure scientific excellence. Two classes are generally used: the top 10% and the top 1% of the most-cited publications. These publications are identified at the global level for each research field; they may then be aggregated at the institutional or national levels based on the addresses of their authors (see methodological annex). In 2016, almost 20,000 publications issued in 2014 occupied the top centile attracting the most citations in the 3-year window of observation.

The first category of indicators measures the volume of a country's publications which figure among the world most-cited, while the second category measures the share of these publications in the country's total output. These two main types of indicators are presented in detail below.

Figure 7 tracks trends in the volume of the world's most-cited publications produced by the world's top 20 producing countries. As with overall output, by the end of this period the top four producers were the United States, China, the United Kingdom and Germany. China has shot up from 12th place to 2nd, an even more rapid progress for highly-cited publications than that seen for publications in general (see Figure 3). India on the contrary has remained in 14th place in terms of its output of publications ranked in the top 1% most-cited. Japan has slipped from 4th to 11th place. France started the millennium in 5th place, slipping to 7th by 2014 after being overtaken by China (2005), then Australia and Canada in 2014. The latter nations have considerably improved their performance since 2000. France has nonetheless increased its output of highly-cited publications.

Figure 7. Number of publications in the top 1% most-cited, top 20 producing countries, 2000-14



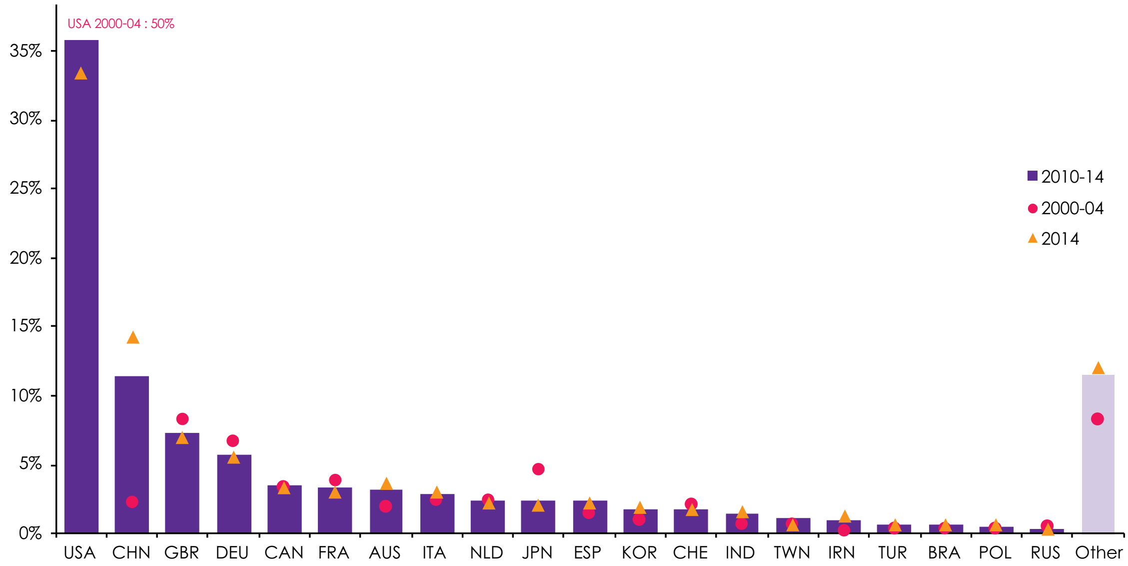
www.hceres.fr/OSTReport2019-Fig-7

Source: Computed by OST using WoS

The evolution of the international rankings reflects trends in the output of highly-cited publications. Figures 8a and 8b show the evolving shares of the top 20 largest producers in the top centile and decile of most-cited publications. They confirm China's rapid progress in both citation classes. The American share has declined, but the USA continues to produce a high percentage of the most-cited publications: in 2010-14 the USA produced 36% of the top 1%, 31% of the top 10% and 20% of all publications (2012-16, Figure 4a).

Figures 8a and 8b also confirm the decreasing weight of Japan in terms of output of highly-cited publications. Between 2000 and 2014 Japan lost ground to Canada, France, Australia, Italy, the Netherlands and Spain in terms of publications in the top 1% (Figure 8a). With regard to the top decile of most-cited publications, Japan is tied with Spain (Figure 8b). Italy's share of both classes has increased, while France's share has stagnated. In 2014, the shares of France, Canada and Italy in the top decile were all around 3.4% (Figure 8b).

Figure 8a. World share of top 1% most-cited publications, top 20 producing countries



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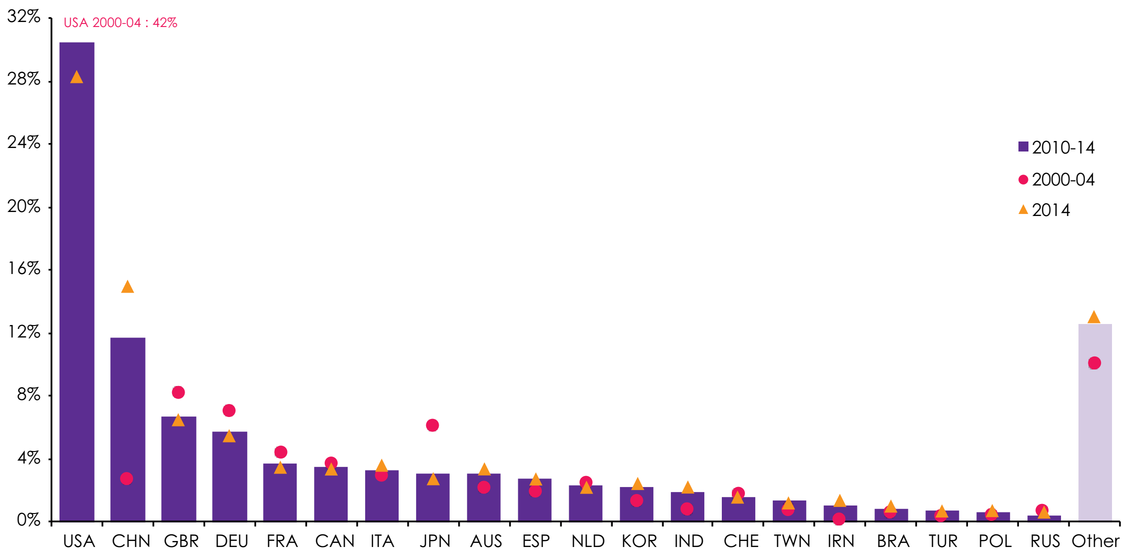
Source: Computed by OST using WoS

Figure 8b. World share of top 10% most-cited publications, top 20 producing countries

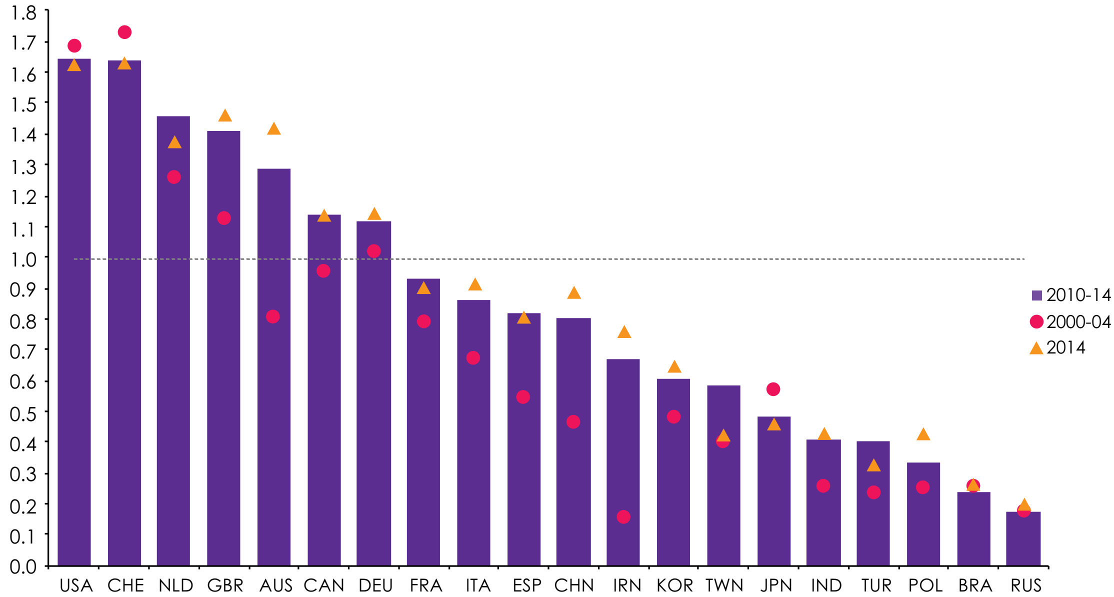


www.hceres.fr/OSTReport2019-Fig-8b

Source: Computed by OST using WoS

Figures 9a and b are based on a size-independent indicator of the intensity of highly-cited publications. The top 1% activity index is the share of these publications in a country's total output divided by the same ratio for the whole world: if a country has an activity index of 1.3, this means the proportion of its total publications ranked in the top 1% is 30% above the world average[13].

Figure 9a. Activity index in the top 1% most-cited publications, top 20 producing countries



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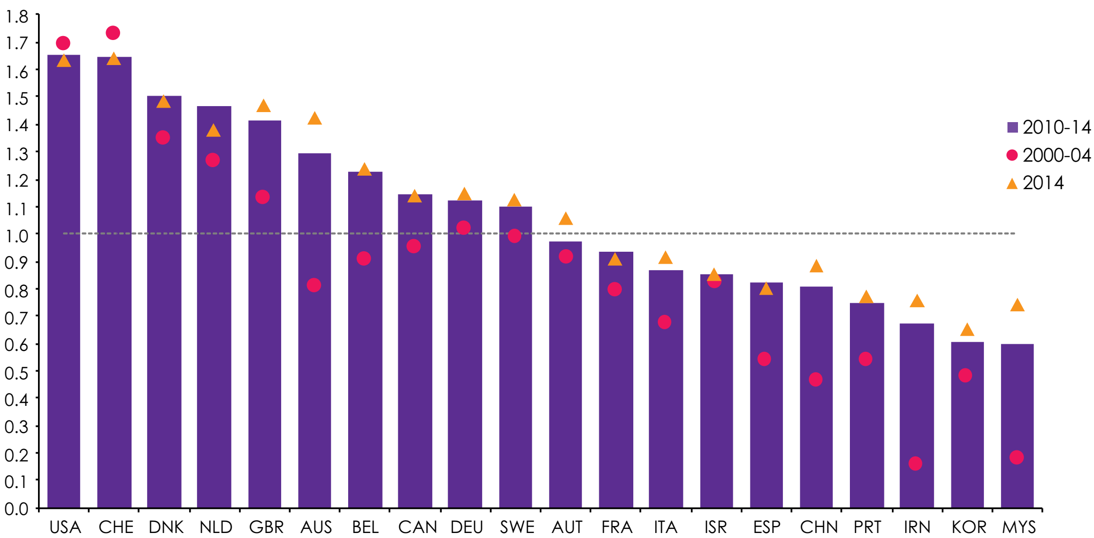
Source: Computed by OST using WoS

Figure 9b. Activity index in the top 1% the most-cited publications[a]: 20 countries with the highest scores



a. Only countries with more than 10,000 publications in 2014 are included, ruling out Finland and Singapore.

www.hceres.fr/OSTReport2019-Fig-9b

Source: Computed by OST using WoS

The ranking of the world's top 20 producers based on the size-independent indicator (Figure 9a) is different from the ranking based on the size-dependent indicator (Figure 8a). The USA and Switzerland rank first and second in terms of activity in the top 1%, China being 11th rather than second for the world share of the top 1% most-cited publications. Since the turn of the century, this indicator of excellence

13. See the methodological annex for more details on definitions.

denotes strong progress by the UK and Australia, ranked 3rd and 4th respectively in 2014, overtaking the Netherlands whose performance slipped over the same period.

Among the world's leading producers of academic publications, France is ranked 8th for the top 1% activity index (Figure 9a), while ranking 6th in terms of the world share of most-cited publications (Figure 8a). Italy has progressed more than France since 2000, and its share of highly-cited publications is now similar. Besides, in 2014, the two countries have the same top 1% activity index (Figure 9a)[14].

Figure 9b includes the 20 countries for which the proportion of publications in the top 1% is the highest. The first two countries are still the USA and Switzerland, but Denmark now comes third. Belgium comes before Canada and Sweden and Austria before France. France is in 12th position, compared with 8th in the chart featuring only the 20 largest producers (Figure 9a).

China has made substantial progress in its activity in highly-cited publications. Over the period, it overtook both South Korea and Japan for the top 1% activity index and has come close to France and Italy, above Spain and Israel (Figure 9b).

2.3.3. Country distribution and international mobility of Nobel laureates

Indicators of the scientific impact of publications take into account the addresses of the institutions to which their authors are affiliated. The international mobility of researchers thus has an impact on bibliometric indicators. Given the considerable asymmetry in the impact of publications, it is particularly interesting to analyse the movements of the most influential researchers. Various studies have sought to analyse the careers of these researchers, and particularly their international mobility. The most influential researchers can be defined as those who have received certain prestigious prizes, or else as those who are most frequently cited in scientific publications. In terms of international mobility, both criteria yield similar conclusions.

One recent study analyses the geographical mobility of those researchers who received Nobel Prizes in chemistry, physics or medicine between 1994 and 2014 (Schlagberger et al. 2016). It identifies the affiliation of Nobel laureates at three key dates: when they received their doctoral degree, when they did the work which earned them the prize, and when the prize was awarded. The appendix to this article specifies the names of the laureates, the research for which they won the Nobel and their institutional affiliations at each of the three key dates. Here the same method is used to update the data up until 2017, using information obtained from the Nobel Foundation website. The results below thus cover the period 1994-2017, taking in 179 laureates.

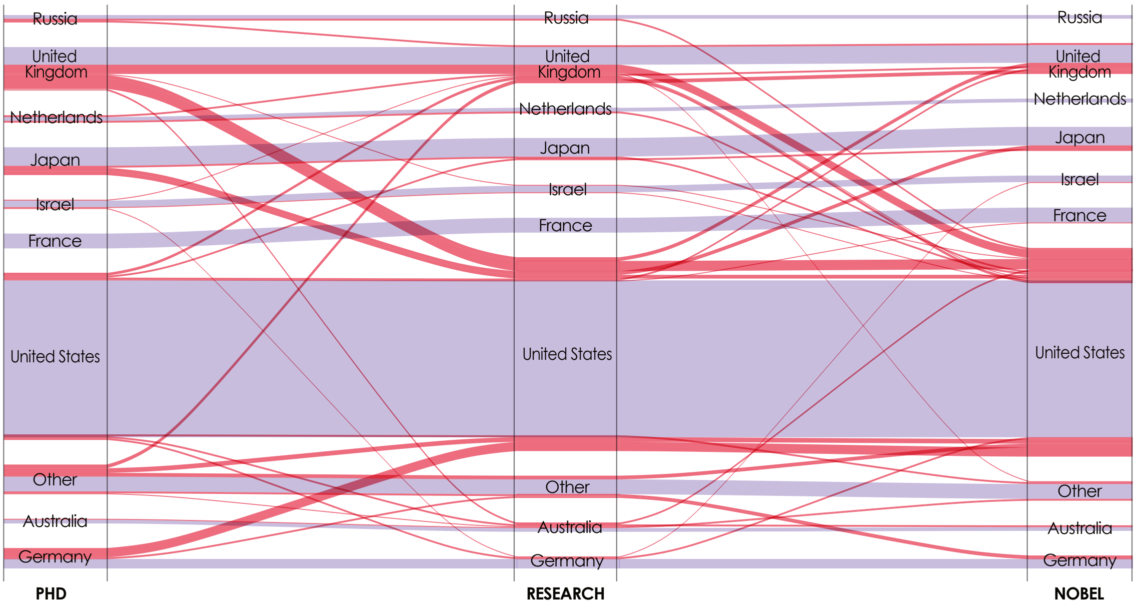
This analysis highlights the high degree of institutional mobility among Nobel laureates: only 10% of laureates stayed at their *alma mater* (Schlagberger et al. 2016). Their international mobility is not as strong, but around a quarter had worked in at least two different countries over the course of their career. Some of the laureates were affiliated to three different institutions in three different countries at the three key dates.

Figure 10 illustrates the international mobility of Nobel laureates over the course of their career, highlighting the tendency of these researchers to flock to American institutions. Holders of doctorates from American universities won by far the greatest number of Nobel Prizes[15] and, furthermore, many Nobel laureates from other countries moved to American universities after their doctoral studies, either doing Nobel-winning work there or moving later on in their careers. Some recipients also left American institutions after their doctoral studies, many of them heading to universities in the UK, Japan, Australia or Germany.

14. Annex A3 provides a comparison of countries based on the proportion of their national published output which ranks in the top decile of most-cited publications based on Scopus data.

15. Furthermore, Schlagberger et al. (2016) point out that a high proportion of Nobel Prize winners come from just a handful of American universities.

Figure 10. International mobility of Nobel Prize winners, 1994-2017



www.hceres.fr/OSTReport2019-Fig-10

Source: Computed by OST based on data from Schalgberger et al. (2016) and the Nobel Prize website.

British researchers appear to be particularly mobile, especially towards American institutions: more than a quarter of laureates who received their doctorate from British universities were no longer in the United Kingdom when they did their Nobel-winning work. Conversely, a number of future laureates moved to British universities from the United States, the Netherlands, Sweden and Russia. Canadian researchers are also quite mobile: of the three Nobel laureates who did their doctoral studies in Canada, one subsequently moved to the United States and another moved to the United Kingdom. Australia, traditionally a country of immigration, has attracted a number of Nobel laureates, some of whom subsequently moved elsewhere. Japanese laureates tend to stay in Japan, or to move between Japan and the United States. French laureates are among the most settled.

Table 4 summarises the results for different countries, including laureates from smaller countries, who are grouped together in the 'Other' category in Figure 10. Over 50% of future Nobel laureates received their doctoral degrees from American institutions, while 58% did their Nobel-winning work in the USA and almost two-thirds of recipients were based at American institutions later in their careers. These percentages far exceed the American share of highly-cited publications, with 37% in the top 1% (2010-14, Figures 8a)[16]. The same is true of the United Kingdom, Japan, France, Germany and Russia. China, Canada and Australia, on the other hand, have a higher share of highly-cited publications than of Nobel laureates. Between 1994 and 2017, just one Nobel Prize was awarded to a Chinese researcher. Two Chinese researchers shared the Nobel Prize for physics in 1957, but thereafter there was no Chinese laureate in the scientific categories until 2015, when Tu Youyou won for her work on malaria.

16. This share is as high as 41% in the top 0.1% of most-cited publications (data not reproduced here).

Table 4. Nobel Prize laureates by country of affiliation, 1994-2017

Stage of the career of the laureates	Country of affiliation institutions	Number of laureates[a]	Share of laureates	Number / 100,000 researchers
Ph.D./M.D. obtained	USA	90.0	50.3%	8.0
	UK	23.5	13.1%	10.4
	Japan	15.0	8.4%	2.3
	Germany	11.0	6.1%	3.7
	France	8.0	4.5%	3.8
	Israel	5.0	2.8%	8.4
	Russia	4.0	2.2%	0.8
	Canada	3.0	1.7%	2.3
	Switzerland	2.5	1.4%	9.3
	Australia	2.5	1.4%	3.2
	Norway	2.0	1.1%	8.1
	Belgium	1.0	0.6%	2.7
	Italy	1.0	0.6%	1.1
	China	1.0	0.6%	0.1
	Turkey	0.5	0.3%	1.1
Prize-winning work	USA	104.5	58.4%	9.3
	UK	20.5	11.5%	9.0
	Japan	12.0	6.7%	1.8
	France	8.0	4.5%	3.8
	Germany	6.5	3.6%	2.2
	Australia	5.0	2.8%	6.4
	Israel	4.5	2.5%	7.6
	Netherlands	3.0	1.7%	5.6
	Russia	3.0	1.7%	0.6
	Norway	2.0	1.1%	8.1
	Switzerland	2.0	1.1%	7.4
	Sweden	2.0	1.1%	3.8
	Canada	2.0	1.1%	1.5
	Denmark	1.0	0.6%	3.2
	Belgium	1.0	0.6%	2.7
	Finand	1.0	0.6%	2.6
	China	1.0	0.6%	0.1
Nobel Prize awarded[b]	USA	112.5	62.8%	10.0
	UK	16.5	9.2%	7.3
	Japan	13	7.3%	2.0
	France	8.5	4.7%	4.0
	Germany	7.0	3.9%	2.4
	Israel	4.0	2.2%	6.7
	Australia	3.0	1.7%	3,8
	Norway	2.0	1.1%	8.1
	Switzerland	2.0	1.1%	7.4
	Netherlands	2.0	1.1%	3.7
	Canada	2.0	1.1%	1.5
	Russia	2.0	1.1%	0.4
	China	1.5	0.8%	0.1
	Denmark	1.0	0.6%	3.2
	Belgium	1.0	0.6%	2.7
	Sweden	1.0	0.6%	1.9
Total number of laureates	World	179	100%	-

a. When a laureate is affiliated with two different institutions in two different countries for at least one of the three key moments (e.g. holding two doctoral degrees from different universities), fractional counting is used.

b. Nobel Prize in physics, chemistry or medicine.

www.hceres.fr/OSTReport2019-Tab-4

Source: Computed by OST based on data from Schalgberger et al. (2016) and the Nobel Prize website.

Given the exceptional nature of the Nobel Prize and the power of attraction of the countries most heavily invested in academic research, it is understandable that the distribution of these international distinctions should evolve more slowly than the distribution of citations, which more rapidly reflect the emergence of dynamic new centres of scientific research. Israel is something of an exception, as this small and relatively young nation does not count among the top 20 producers of scientific publications, but nonetheless has more Nobel laureates than the Netherlands.

The Scandinavian countries, Belgium and Switzerland produce few doctoral students who go on to win Nobel Prizes, but tend to hold onto their top researchers. Germany and Japan lose 4 and 2 Nobel-winning researchers (respectively) out of 10 before attribution of the prizes (net incoming-outgoing). Five researchers who obtained their doctoral degrees in Germany subsequently moved to the United States to continue their research and remained there, while in the meantime one Swedish researcher moved to Germany towards the end of his career. Finally, France maintains a stable contingent of 8 Nobel Prize winners at all three of the key stages considered here. Due to the higher degree of mobility among German researchers, in comparison France's position is more favourable for Nobel laureates than it is for future laureates.

Figure A2 in annex 2 focuses on Nobel laureates who have changed countries at least once over the course of their career. The flows between countries are clearer in this visualization. The figure clearly illustrates the growing attractiveness of the United States as academics advance in their careers, and also highlights the special place occupied by the United Kingdom in the global network of academia. France only appears at the point when the Nobel Prize is awarded, since no Nobel laureate with a doctorate from a French university was internationally mobile thereafter. But one future laureate did move from the United States to France. Russia, on the contrary, has seen half of its Nobel-winning researchers emigrate, while no future laureate has moved to Russia. Russia therefore does not feature in the "Nobel" section of the graph.

Analysing the academic careers of researchers who have won other prestigious prizes, or the world's highly-cited researchers, yields similar results in terms of the unique position of the United States, similar to the country's position for highly-cited publications (Rodriguez-Navarro 2016). American universities produce a large proportion of the world's most influential researchers, while also attracting students and researchers from all over the world by providing them with excellent conditions in which to continue their work. This dual phenomenon exists across the board, but is particularly pronounced in certain disciplines such as economics, psychology and clinical medicine (Panaretos and Malesios, 2012). Analysing American scientific output reveals a clear specialisation in economics, since the USA is home to a large number of the most prestigious institutions in this field, and the country is highly attractive to foreign researchers[17]. As such, American universities are home to an extremely high proportion of the highly-cited researchers in the field of economics (Albaran et al. 2014).

2.4. The scientific performance of the European Union

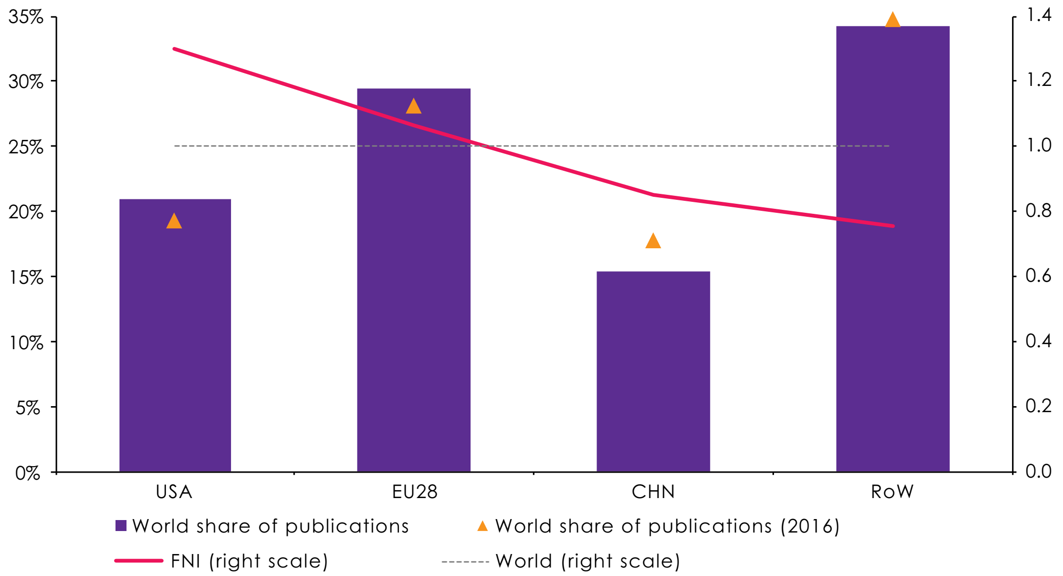
In 2016 the EU accounted for nearly 28% of world output of scientific publications, ahead of the United States and China. The ranking is different in terms of impact, the US being the leading country, ahead of the EU and China. The US is also the leader for its activity in of top 1% most highly-cited publications. Its share of Nobel prize winners is higher than that of Europe. Furthermore, the US is more attractive than the EU when these prize winners move from one institution to another during their career.

2.4.1. World share and academic impact of EU publications

Since 2000, the EU's share of world publications has decreased less than that of the US (EU 2018); in 2016, its world share was 28% and that of the US 19% (Figure 11). The 3-year impact of publications from 2012-14 was 1.3 for the US, 1.1 for the EU and 0.9 for China.

17. A few indicators focusing specifically on the field of economics are included in section 4.3.

Figure 11. World share of publications and impact: EU28, USA and China, 2012-14



www.hceres.fr/OSTReport2019-Fig-11 *Source: Computed by OST using WoS*

In terms of highly-cited scientific publications, the share of the EU has declined much less than that of the US. As a result, the EU has a higher share of the top 10% than the US (31% against 28% for 2014 publications). For the top 1% of most-cited articles, despite the strong decrease in its share since 2000, the US remains the global leader with 33% of the world total (Figure 12a). China has increased its share of the top 1% sevenfold since the beginning of the century. In 2014, China's share represented 43% of that of the US and 48% of that of the EU.

Both indicators in Figure 12b show the same trends. The performance of the United States has been eroded slightly, but in 2014, the proportion of top 1% in its total publications was still 65% above the world average. The performance of the EU and China increased steadily. The performance of the EU, however, is at the world average for the top 1% and 10% above the world average for the top 10%.

Figure 12a. Share of world top 1% and top 10% most-cited publications, USA, EU28 and China

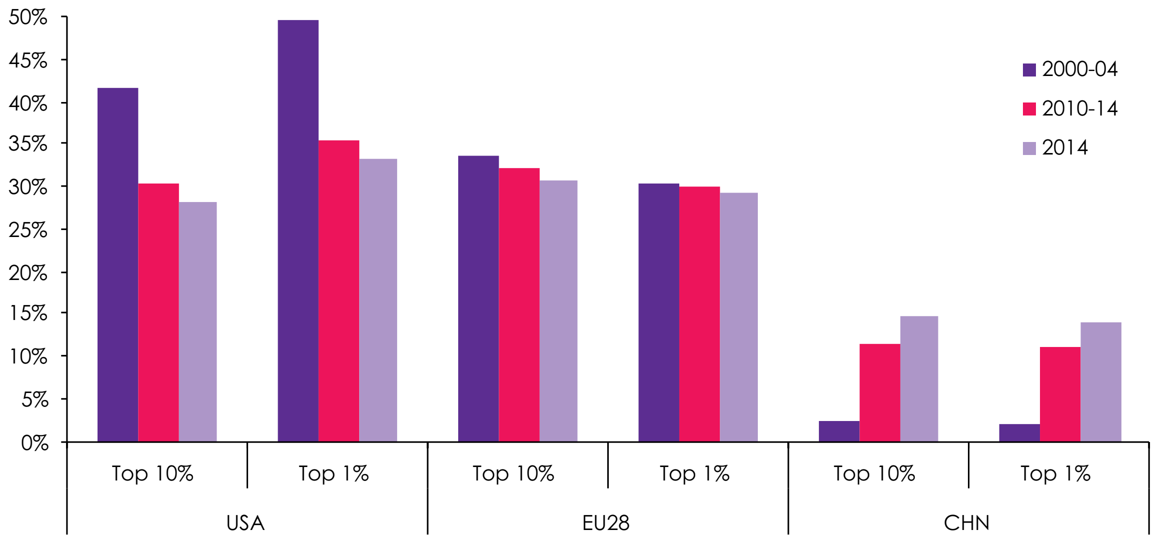


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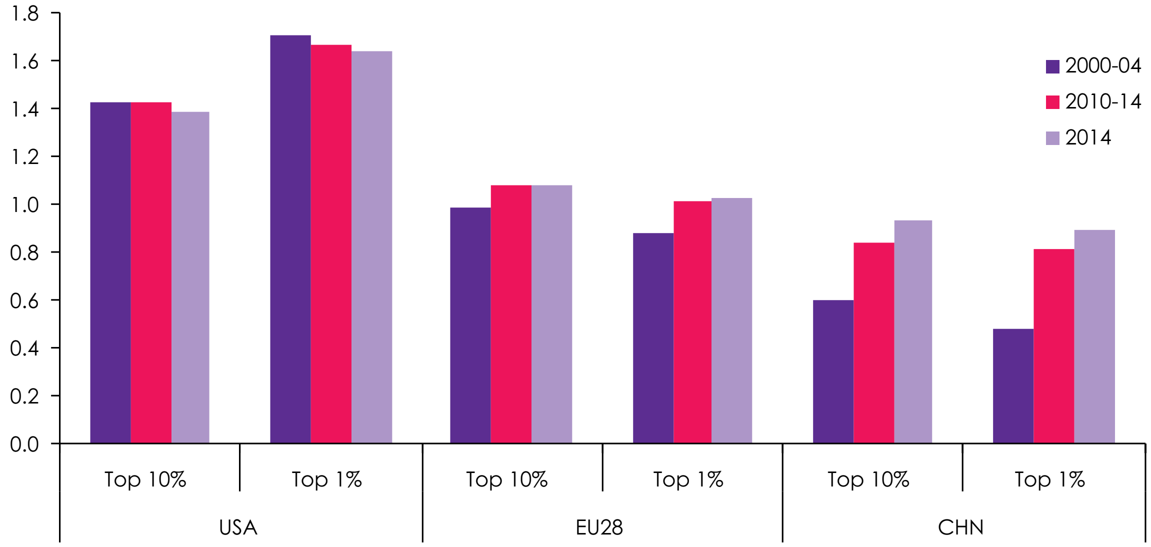
Figure 12b. Activity in the top 1% and top 10% most-cited publications USA, EU and China

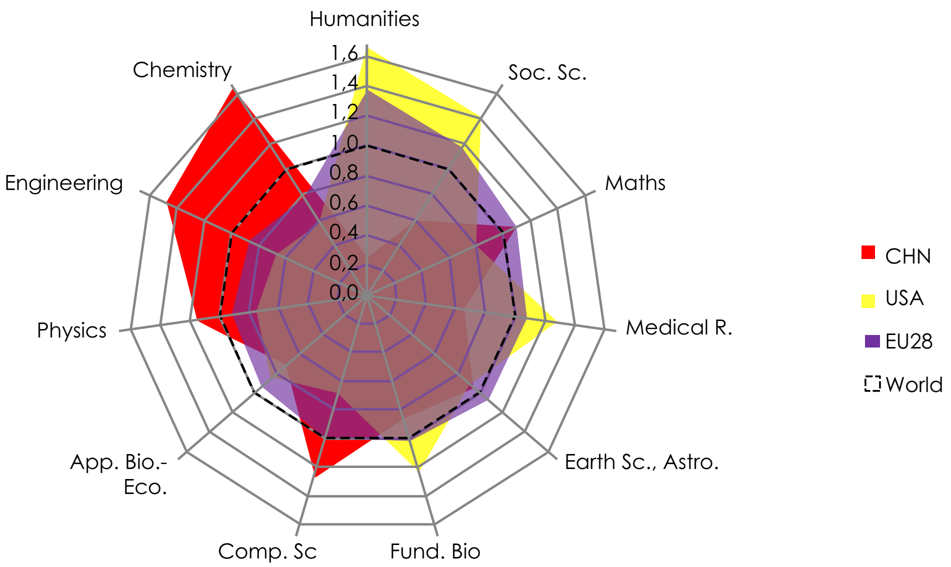


www.hceres.fr/OSTReport2019-Fig-12b

Source: Computed by OST using WoS

The EU has a much more balanced scientific profile than both the USA and China. The EU is less specialised* than the US in humanities, social sciences and medical research (Figure 13). Its share of publications in mathematics is about 10% above the share of the discipline for total world publications. Its specialisation index[18] in the discipline is thus equivalent to that of China. The EU as a whole is, however, not specialised in China's major disciplines, i.e. physics, engineering and chemistry. Its share of publications in computer science is equivalent to that of the world, while China's share is more than 20% above the world average and the US' share is 31% below. Overall, the EU's scientific profile is closer to that of the US than to that of China.

Figure 13. Specialisation Index, EU28, USA and China, 2016



www.hceres.fr/OSTReport2019-Fig-13

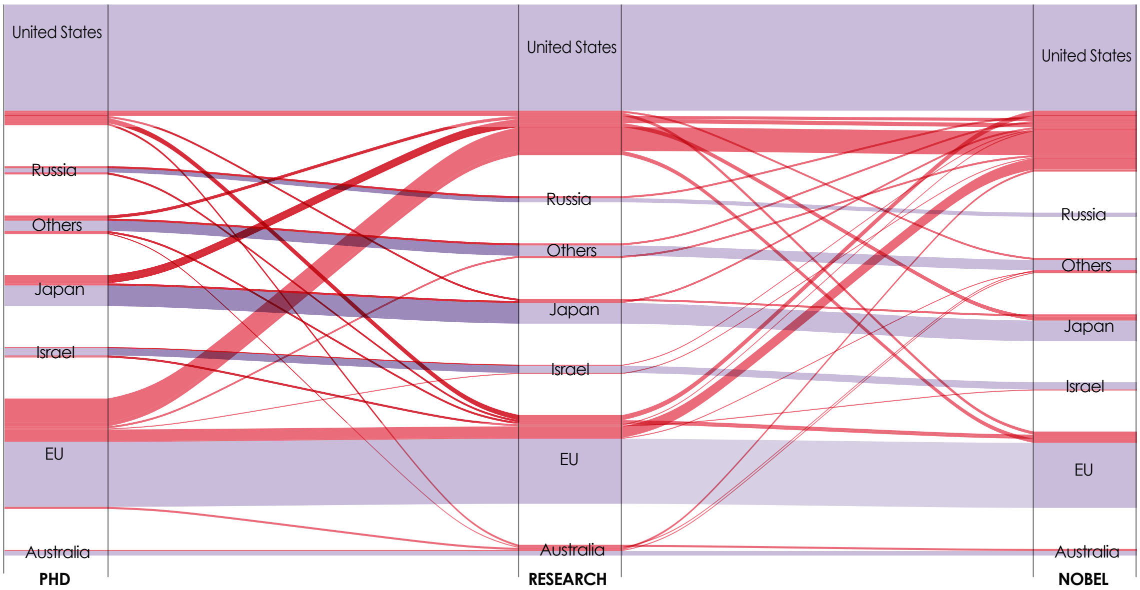
Source: Computed by OST using WoS

18. The specialisation index compares the share of a given discipline in total publications from a country with the same ratio for the whole world (see glossary and methodology).

2.4.2. Mobility of Nobel laureates to and from the EU

Figure 14 corresponds to Figure 11 above after consolidation of the EU countries. Of the 179 laureates recognised in the period 1994-2017, 29% did their doctoral studies in an institution within the EU, while 50% obtained their doctorate from an American institution. Among the future Nobel laureates 61% of those who got their doctorates from European institutions then went on to spend the rest of their career in the EU, while the same is true of 92% of laureates who earned their Ph.D. degrees in the USA. More than a quarter of future laureates who graduated from European universities then moved to the USA before winning their Nobel Prize.

Figure 14. Mobility of Nobel Prize winners to and from the EU, 1994-2017

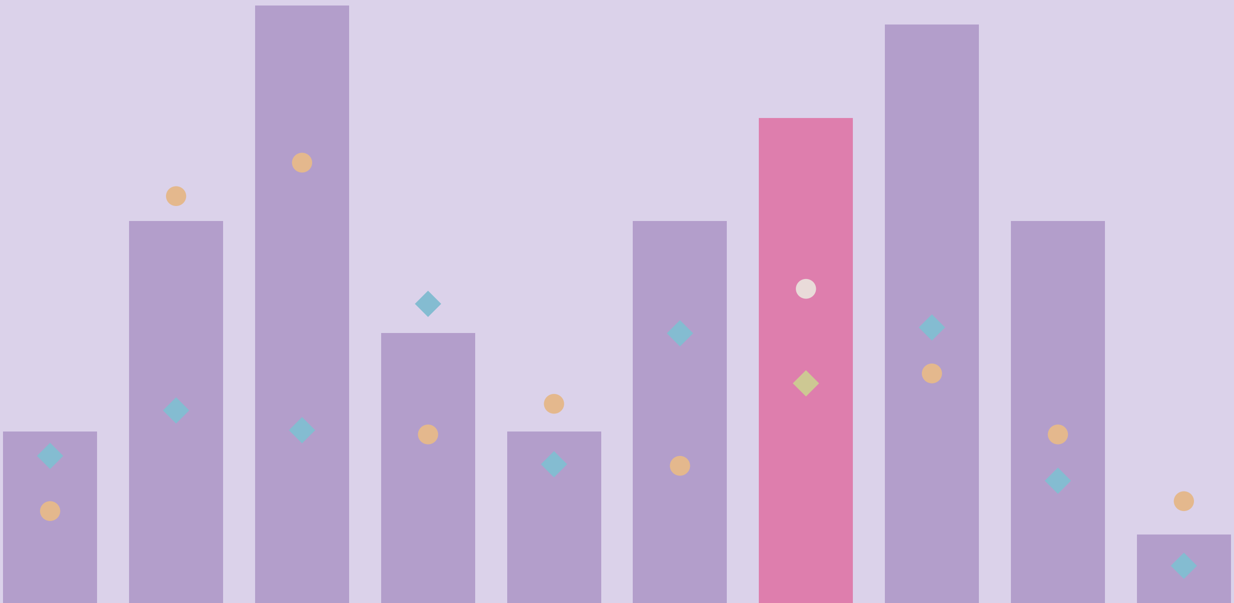


www.hceres.fr/OSTReport2019-Fig-14

Source: Computed by OST based on data from Schalgberger et al. (2016) and the Nobel Prize website

All in all, over their whole career span, researchers from European institutions who win Nobel Prizes in the scientific categories tend to migrate to the United States, with few returning to Europe. The EU thus makes a significant contribution to increasing the share of Nobel laureates affiliated with American universities at some point in their career. Even without this contribution, the majority of future Nobel laureates earned their doctorates at American universities.

3 A disciplinary perspective on world publications



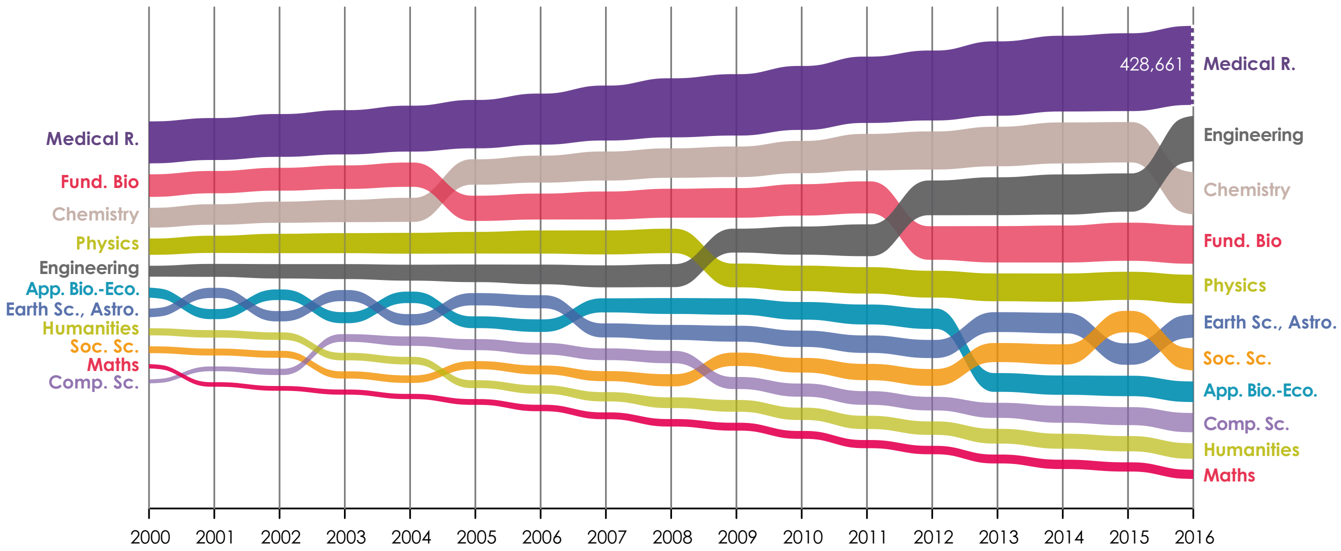
The respective shares of the major scientific disciplines in total world publications vary considerably in size. These differences can be ascribed to a combination of two factors: on the one hand, not all disciplines are allocated the same resources and number of researchers and, on the other hand, publication practices differ greatly from one discipline to the next. Researchers in different fields publish at different rates, and their scientific output may take the form of journal articles, conference proceedings or books, in different proportions[19]. The average number of authors involved in scientific contributions also varies between disciplines.

The disciplinary classification* used here is explained in detail in the methodological annex (A1).

3.1. Evolution of world scientific publications by discipline

In 2016, medical research yielded a total of 430,000 publications, compared with 50,000 in mathematics. Figure 15a shows that output has increased in all disciplines since 2000, but to varying degrees, thus leading to changes in their respective shares of total world output.

Figure 15a. World scientific publications by discipline, 2000-16



www.hceres.fr/OSTReport2019-Fig-15a

Source: Computed by OST using WoS

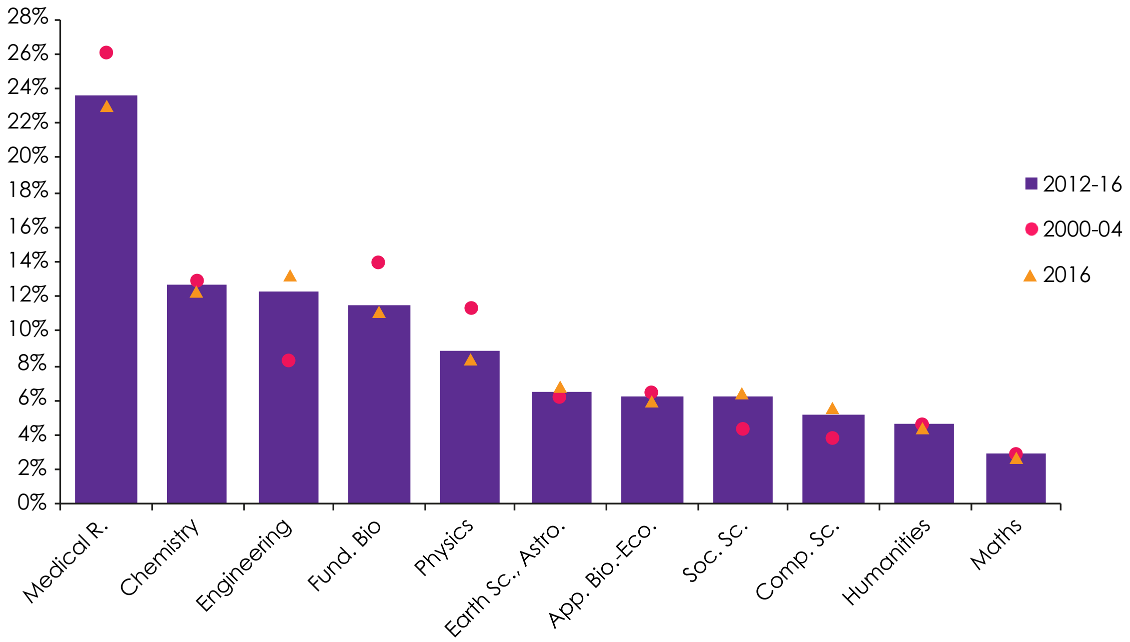
19. OST database focuses on articles and contributions in conference proceedings, which means that some disciplines are less represented (see the methodological annex).

Medical research remains far and away the first discipline in terms of publications. Fundamental biology was overtaken by chemistry in 2005 and by engineering in 2012. Engineering now occupies the second spot, having overtaken chemistry in 2016. The number of publications in physics was overtaken by publications in engineering in 2009. Physics has thus moved down from 4th to 5th place. Applied biology-ecology now accounts for roughly the same number of publications as earth sciences-astronomy-astrophysics and social sciences, but the latter disciplines have grown more rapidly since 2000.

Computer science and the humanities have experienced contrasting dynamics over the same period: computer science has risen from 11th to 9th position in terms of total volume of publications, while the humanities have sunk from 8th to 10th place.

Figure 15b offers a further perspective, showing the evolving breakdown of total world publications between the major disciplines between 2000 and 2015. While retaining first position, medical research has seen its share of total publications fall to 23%. Engineering and social sciences have expanded their shares by almost 50%, while the shares of fundamental biology and physics have slipped. The share of chemistry has remained fairly stable (12% in 2016), while engineering has grown considerably to reach 13%.

Figure 15b. Distribution of world scientific publications by discipline[a], 2000-16



a. Less than 1% of publications are not attributed; they are in part "multidisciplinary".

www.hceres.fr/OSTReport2019-Fig-15b

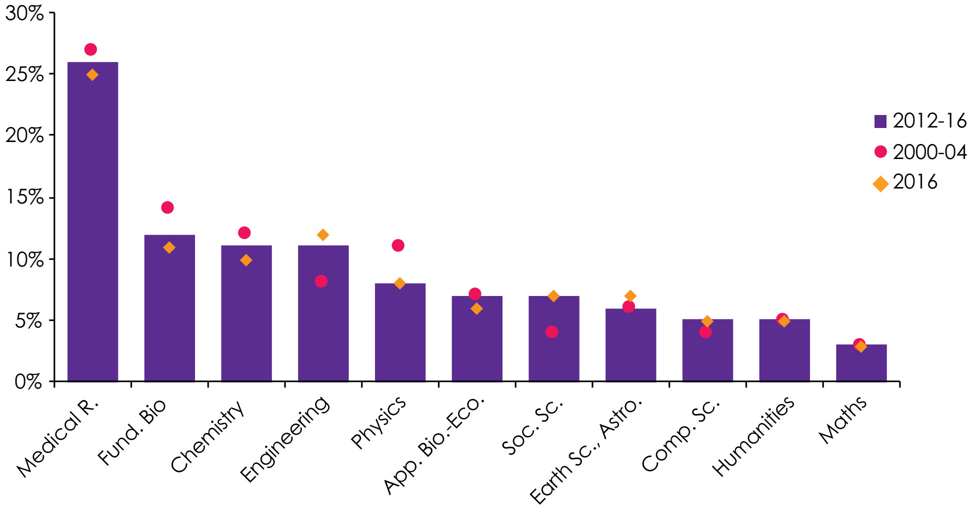
Source: Computed by OST using WoS

Box 3 shows how the disciplinary distribution of world publications has been influenced by China's scientific profile, as a result of the strong increase in Chinese output.

Box 3. The effects of China's rise on bibliometric indicators. 3. Disciplinary profile of publications

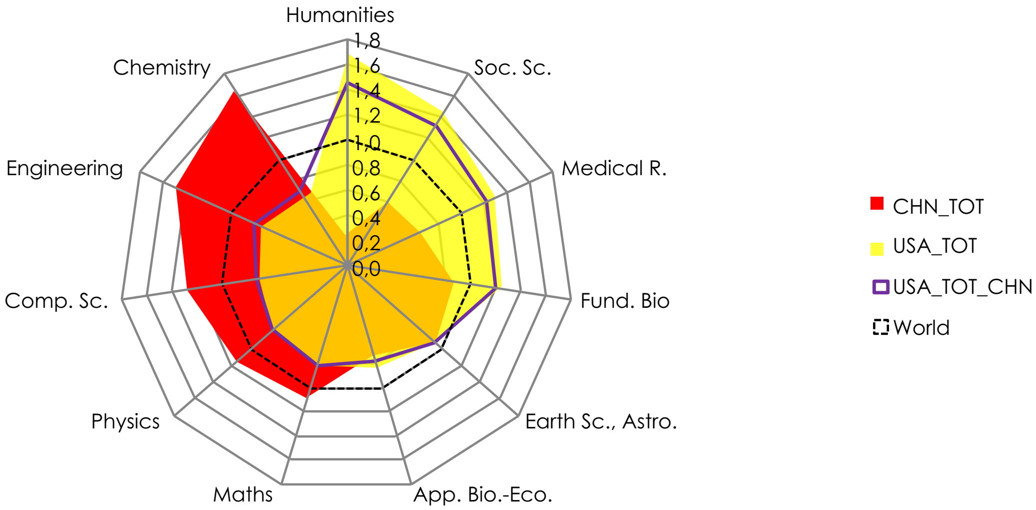
In a world without China (see Box 1), the disciplinary breakdown of world publications would be noticeably different. Medical research would account for an even larger proportion of total output (25% in 2016, Figure B3a), while the shares of chemistry and engineering would fall to 10% and 12% respectively. In a world without China, the third most prolific publishing discipline would be fundamental biology, with chemistry in fourth place. In this counterfactual world, engineering would still have moved up to second place since the start of the century.

Figure B3a. Scientific publications by discipline: world without China, 2000-16



These differences can be attributed to the disciplinary profile of Chinese publications. Figure B3b illustrates China's high specialisation index in chemistry and engineering.

Figure B3b. US specialisation index: world with and without China, 2016



www.hceres.fr/OSTReport2019-Fig-B3a | www.hceres.fr/OSTReport2019-Fig-B3b

Source: Computed by OST using WoS

As Figure B3a shows, a world without China would produce far fewer publications in the fields of chemistry and engineering, with the effect of automatically increasing the specialisation indices of other countries in these disciplines. Figure B3b shows this effect in action: in a world without China, the US specialisation indices for chemistry and engineering are increased (USA_TOT_CHN). Meanwhile, a world without China would produce a higher proportion of publications in social sciences and humanities, as well as medical research. As a result, the United States would appear relatively less specialised in these disciplines.

3.2. The case of mathematics

In order to analyse world publications in mathematics and countries' production in the discipline, two different corpora were explored, using two different levels of classification and a bespoke benchmark group of comparable countries[20].

The first corpus corresponds to those journals which the classification used in the OST database assigns to the general discipline of mathematics, in keeping with the rest of this report. The largest part of indicators is calculated for this broad corpus. The second corpus is more selective, consisting of articles published in journals considered by the Australian Mathematical Society to be the most prestigious; a list of these A* journals is given in Annex 4. The indices calculated for this highly selective corpus are presented in a series of boxes. Between 2000 and 2016, the OST database records almost 650,000 publications in mathematics; the corpus of A* journals contains just over 81,000 entries for the same period[21]. The indicators calculated for both corpora correspond to the same definitions used elsewhere in this report[22]. The only difference with other chapters in this report is the calculation of impact that takes into account a 5-year citation window, considering the specific time scale of citations in mathematics[23].

This analysis covers all publications in the four research fields that make up the discipline, as per the classification used in the OST database (table 5). It is based on the classification of journals in the Web of Science database[24]. Journals or conferences specifically devoted to the application of mathematical methods in other disciplines, such as biology, are not taken into account.

The Mathematics benchmark group is made up of countries that are among the largest publishers in mathematics or are most specialised in this discipline, or are home to at least one winner of a prestigious international mathematics prize[25] who published work in the period 2000-16. The Mathematics benchmark group thus contains 17 countries: Austria, Belgium, Canada, China, France, Germany, Iran, Israel, Italy, Japan, the Netherlands, Romania, Russia, Spain, the United Kingdom, and the United States.

20. A further analysis on a corpus comprising the publications of recipients of the major international maths prizes is included in the French version of this report (OST 2018). Its results are consistent with what follows, in particular with respect to the field of fundamental mathematics, in which those laureates concentrate their publications.

21. Fractional counting. Table A4b in the annex shows the country-by-country breakdown for these corpora and for the top 1% most-cited publications in mathematics, corresponding to around 6,000 publications.

22. Dubois et al. (2013) use their own specific corpus and impact indicator, based on their analysis of mathematics journals which takes into account factors such as the average number of pages.

23. See the methodological annex for details on the choice of the citation window.

24. The WoS subject categories; see the methodological annex.

25. Fields, medal, Abel, Gauss and Wolff in mathematics prizes.

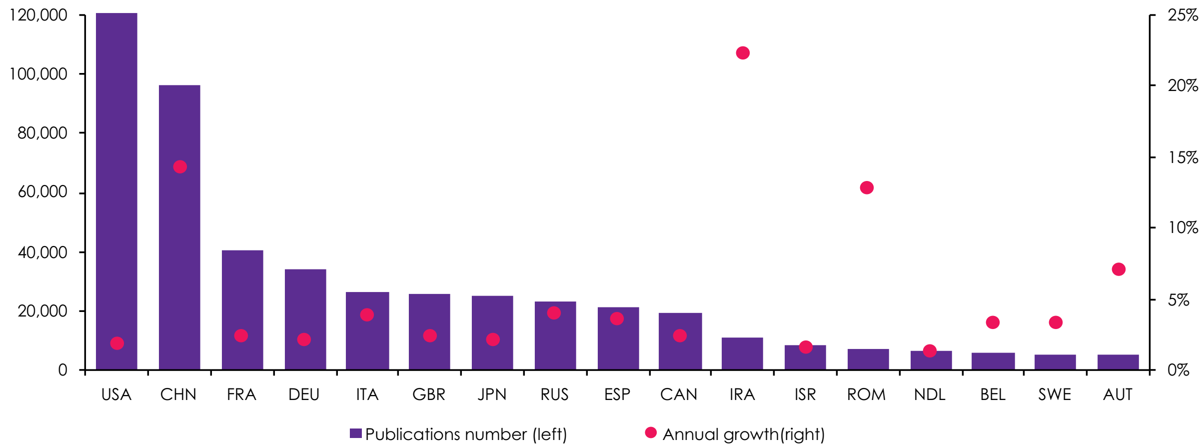
Table 5. Classification of Research fields in mathematics

Name (short name)	Description in the Web of Science database
Mathematics (F. Maths)	It covers resources having a broad, general approach to the field. The category also includes resources focusing on specific fields of basic research in Mathematics such as topology, algebra, functional analysis, combinatorial theory, differential geometry and number theory.
Mathematics, Applied (A. Maths)	It covers resources concerned with areas of mathematics that may be applied to other fields of science. It includes areas such as differential equations, numerical analysis, nonlinearity, control, software, systems analysis, computational mathematics and mathematical modelling. Resources that are concerned with mathematical methods and whose primary focus is on a specific non-mathematics discipline (except biology) such as psychology, history, economics etc., are covered in the MATHEMATICS, INTERDISCIPLINARY APPLICATIONS category. Resources focusing on mathematical biology are covered in the MATHEMATICAL & COMPUTATIONAL BIOLOGY category.
Statistics & Probability (Stat. & Proba.)	It covers resources concerned with methods of obtaining, analysing, summarising, and interpreting numerical or quantitative data. Resources on the study of the mathematical structures and constructions used to analyse the probability of a given set of events from a family of outcomes are also covered.
Mathematics, Interdisciplinary Applications (Maths IA)	It includes resources concerned with mathematical methods whose primary focus is on a specific non-mathematics discipline (except biology) such as psychology, history, economics, etc. Resources that deal with mathematical biology are covered in the MATHEMATICAL AND COMPUTATIONAL BIOLOGY category. Resources that focus on specific mathematical topics such as differential equations, numerical analysis, nonlinearity, etc., are covered in the MATHEMATICS, APPLIED category.

3.2.1. Publications and specialisation in mathematics of the major producers

In the OST database, the number of publications in mathematics grew from 24,000 in 2000 to 50,000 in 2016, which corresponds to an average annual rate of growth of just over 5%. The United States was the biggest publisher over the period as a whole, followed by China and then France (Figure 16). The countries in the benchmark group account for 74% of the global mathematical output, and the two biggest producers alone account for a third of that total output.

Figure 16. Publications in mathematics and annual growth rates, Mathematics benchmark group, 2000-16

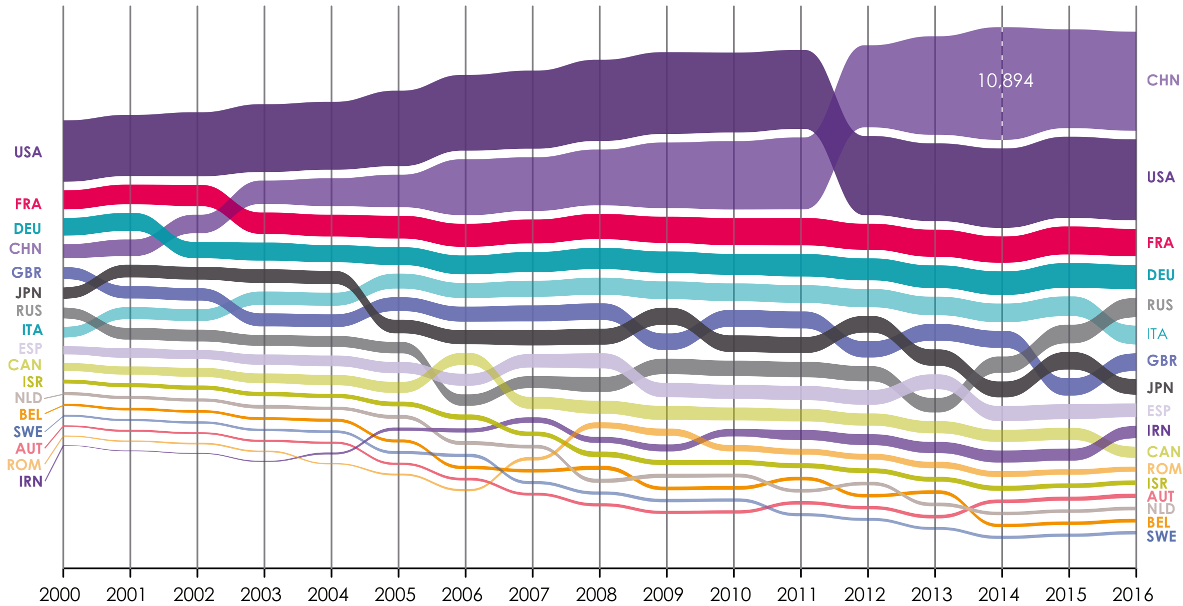


www.hceres.fr/OSTReport2019-Fig-16

Source: Computed by OST using WoS

Among the world's biggest publishers in mathematics, China stands out on account of its 15% rate of year-on-year growth. France and the United States have growth rates of below 3%. Figure 17 illustrates China's rapid development: the volume of Chinese publications overtook that of Germany in 2002, France in 2003 and the United States in 2012. In 2016, China's share of world publications in mathematics exceeded 19%, compared with 16% for the United States. France is the third biggest publisher in mathematics. For the period 2000-16, French publications represent 6% of output. Since the turn of the millennium the United Kingdom, the world's third largest producer of scientific publications, has slipped from 5th to 7th place in mathematics, as Russia and Italy experienced higher growth rates.

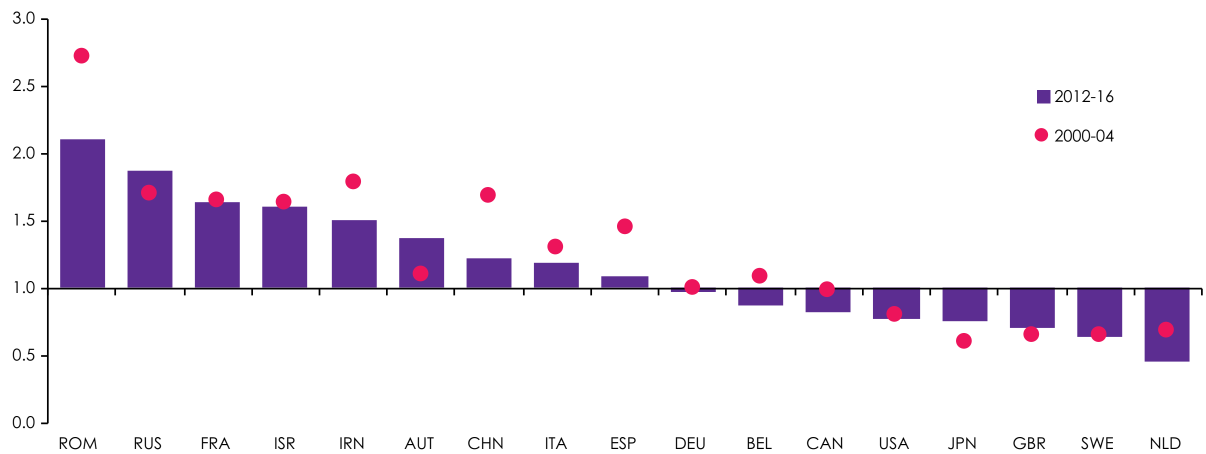
Figure 17. Number of publications in mathematics, Mathematics benchmark group, 2000-16



www.hceres.fr/OSTReport2019-Fig-17 *Source: Computed by OST using WoS*

Over the same period, Russia and Austria have increased their specialisation index in mathematics. Meanwhile, those of Romania, Iran, China, Italy, Spain, Belgium, Canada and the Netherlands have decreased (Figure 18). The ranking of countries most specialised in mathematics has changed little, but France has become more specialised than Iran, Austria and China. Among the leading scientific nations, the United States, the United Kingdom, Germany and Japan are not specialised in mathematics.

Figure 18. Specialisation index in mathematics, Mathematics benchmark group, 2000-16

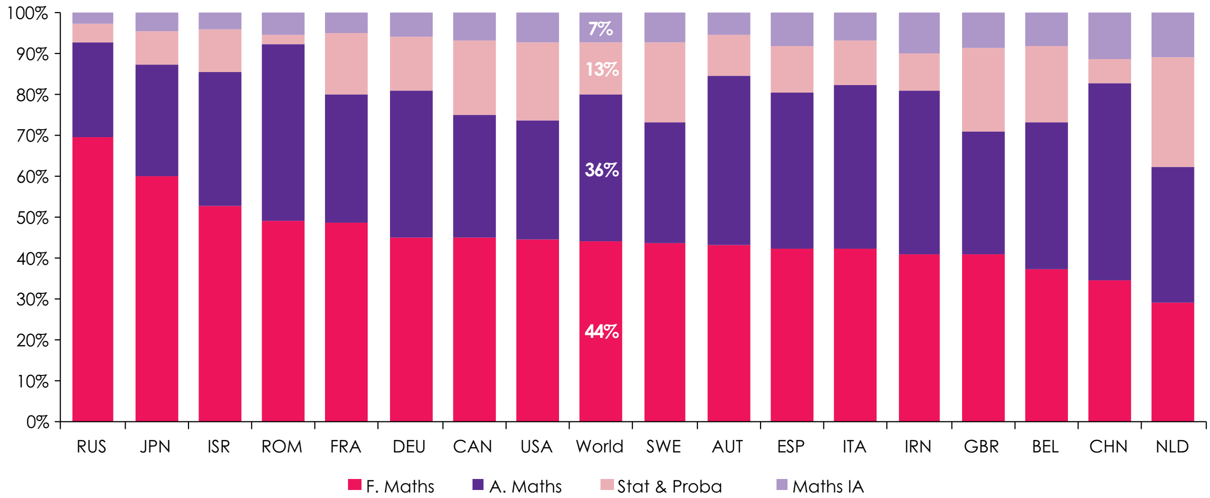


www.hceres.fr/OSTReport2019-Fig-18 *Source: Computed by OST using WoS*

At the global level, the two leading fields of research are Fundamental Mathematics (44%) and Applied Mathematics (36%). Nonetheless, Figure 19 shows how the distribution of publications between different research fields varies considerably from one country to the next. Across the period as a whole, Fundamental Mathematics accounted for more than half of total output in just three countries: Russia, Japan and Israel. In France, Fundamental Mathematics accounts for almost half of total output (49%). The share of Fundamental Mathematics is below 40% for three countries from the benchmark group: the Netherlands, China and Belgium. In China, Applied Mathematics accounts for almost half of total output (49%). The share of Applied Mathematics exceeds 40% in four other countries: Romania, Austria, Iran and Italy.

Statistics & Probability represents 13% of the world's total publications in mathematics. The share of this field tops 20% in the Netherlands and the United Kingdom, and 15% in Sweden, the United States, Canada and Belgium. The share of Mathematics for interdisciplinary applications is just over 7% globally; this field will receive less attention than the three other fields in the present analysis. Nevertheless, this field has been growing in recent years at the expense of Applied Mathematics. This is certainly true in China and the Netherlands, where it now accounts for 11%.

Figure 19. Share of publications in mathematics by field, Mathematics benchmark group, 2000-16



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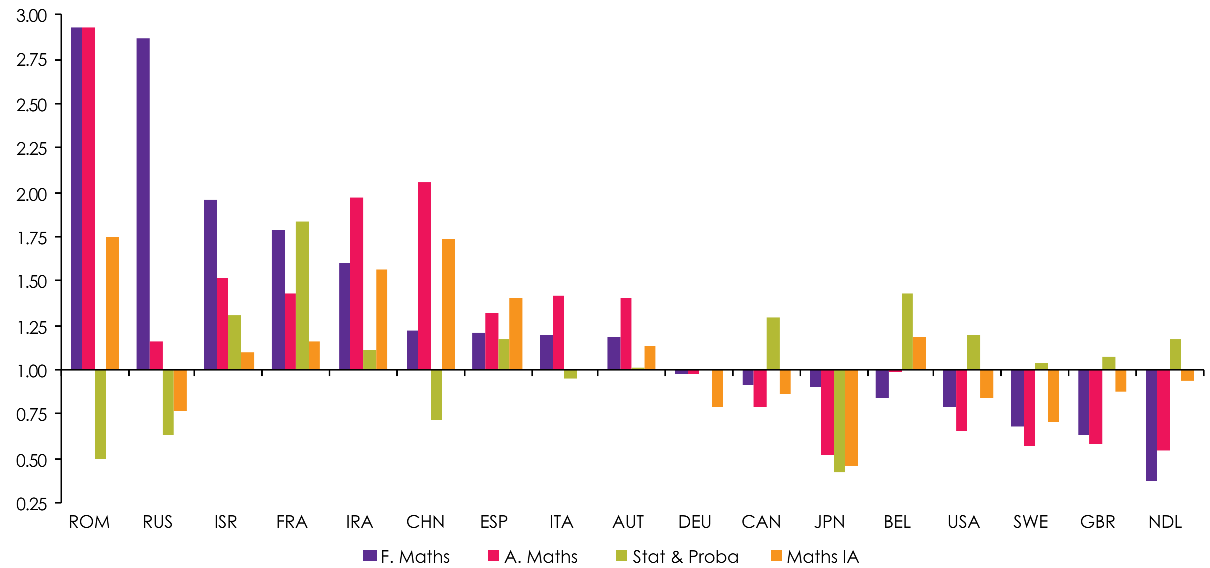
Source: Computed by OST using WoS

Figure 20. Specialisation index by research field, Mathematics benchmark group, 2000-16



www.hceres.fr/OSTReport2019-Fig-20

Source: Computed by OST using WoS

The four countries most specialised in mathematics are also the most specialised in the field of Fundamental Mathematics (Figure 20). France has the lowest specialisation index of the four, but the score is still high at 1.8. Russia and Romania are extremely specialised in this field, with specialisation indices of almost 3. China and Iran are the other two countries in the group specialising most strongly in Applied Mathematics, with a share of publications in this field twice as high as their share in total world publications.

France is one of the rare countries to be specialised in all four domains, along with Israel, Spain and Iran. France is also the country with the strongest specialisation in Statistics & Probability, followed by Belgium, Canada and Israel. Canada, the United States, the Netherlands, the United Kingdom and Sweden are only specialised in the field of Statistics & Probability. On the other hand, the emerging nations included in the Mathematics benchmark group tend not to be specialised in Statistics & Probability. Germany and Japan are not specialised in any of the research fields which make up this discipline.

The share of individual countries in total world publications looks very different when the more selective corpus of top-rated journals identified by the Australian Mathematical Society (AustMS, Box 4) is examined. In this corpus, the USA's share is 32% of world publications, France's share is almost 10% and Germany's 7%. With 6%, China's share is cut in half. Within this corpus, France becomes the second largest producer in the Mathematics benchmark group, surpassing China.

Box 4. A selective corpus of journals in mathematics: 1. Country ranking and breakdown by field

Table B4 highlights differences in publication shares when calculated using the OST database and the corpus of journals rated A* by the AustMS (see Annex A4a). These differences can be largely attributed to the fact that emerging countries have only a small percentage of their output published in A* journals. This corpus accounts for 13% of total world publications in the discipline, but just 5% of Chinese and Romanian publications, 4% of Russian publications and less than 2% of Iranian publications. As a result, the share of high-income and historically research-intensive countries in this corpus is generally higher. The USA's share in this corpus is 60% bigger than its share in the OST database at 32%, France's share grows by 52% to 10% and Germany's share increases by 26% to reach 7%. Nonetheless, the size of this gap varies; it is negative for Japan and Spain.

Table B4. World share of publications in mathematics, OST and A* corpora, 2000-16

Country	World share in OST database, %	World share in A* journals, %	Proportion of publications in A* journals, %	Change of rank between OST and A* corpora	Average nb of publications per year, OST database[b]
USA	19.8%	32.2%	21.3%	0	7,235
China	13.7%	6.3%	5.3%	-2	5,662
France	6.4%	9.7%	19.7%	1	2,356
Germany	5.4%	6.8%	16.4%	1	1,980
Italy	4.1%	4.4%	13.5%	-1	1,546
UK	4.0%	5.9%	18.9%	1	1,485
Japan	4.0%	3.8%	12.4%	0	1,455
Russia	3.6%	1.2%	4.1%	-3	1,352
Spain	3.3%	2.9%	11.4%	0	1,237
Canada	3.0%	3.3%	14.5%	2	1,104
Iran	1.4%	0.2%	1.7%	-6	617
Israel	1.3%	1.7%	17.5%	2	463
Netherlands	1.0%	1.0%	13.7%	1	355
Romania	1.0%	0.4%	4.5%	-2	397
Belgium	0.9%	0.9%	13.0%	1	323
Sweden	0.8%	0.9%	14.5%	1	288
Austria	0.8%	0.9%	14.8%	4	287
Total	**19.8%**	**32.2%**	**21.3%**	**-**	**38,135**

www.hceres.fr/OSTReport2019-Tab-B4 — Source: Computed by OST using WoS

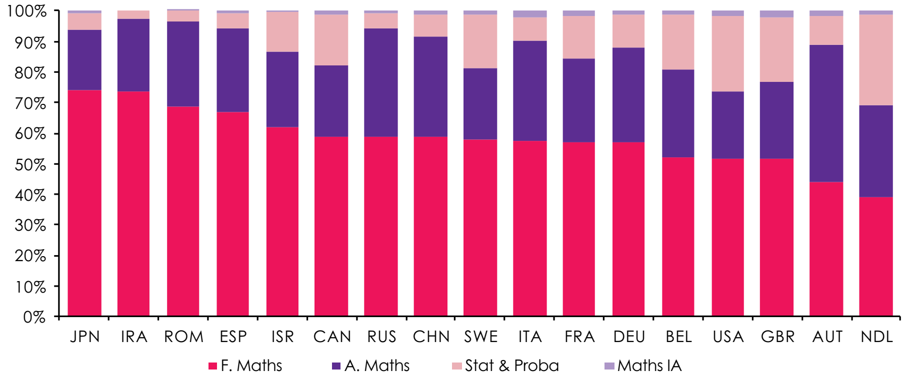
a. Corresponding to the contemporary MathScinet database.
b. Fractional counting, rounded to the nearest whole unit.

Disparities in publication shares between these two corpora have much to do with their composition. The corpus of A* journals is more heavily weighted in favour of Fundamental Mathematics at the expense of both fields of Applied Mathematics (Figure E4). This tends to reduce the share of those countries most specialised in Applied Mathematics, often emerging nations. The reduced share of Applied Mathematics in the corpus of A* journals also has noticeable consequences for other countries. For both France and the United States, the increased share of Fundamental Mathematics comes at the expense of Applied Mathematics and not

Statistics & Probability. For the Netherlands, Statistics & Probability is on a par with Applied Mathematics in the A* corpus. The indicators calculated using the A* corpus are therefore relatively more influenced by publication in Fundamental Mathematics, and to a lesser extent by Statistics & Probability.

The corpus of A* journals is more selective, and this applies to the field of Fundamental Mathematics. This could help to explain the poor performance of Russia, whose share is just a third of what it is in the general OST database, despite the fact that Russian output leans heavily towards Fundamental Mathematics. Russia's poor score takes it out of the world's top 10 sources of mathematical publications, with Israel taking 10th place (Table B4). Using a selective corpus of articles published between 1984 and 2006 in around a hundred journals selected by the American Mathematical Society[a], Dubois et al. (2013) give a ranking of the world's top 10 mathematical producers which is identical to the one here, albeit with slightly different shares. The authors attribute the underrepresentation of Russia to the fact that Russian mathematicians traditionally published their work in Russian language journals, not widely read by the international community. This hypothesis about the Russian mathematical community needs to be checked for a more recent time period.

Figure B4. Distribution of publications by field, Mathematics benchmark group, A* corpus, 2000-16



www.hceres.fr/OSTReport2019-Fig-B4

Source: Computed by OST using WoS

3.2.2. Impact of publications from the Mathematics benchmark group

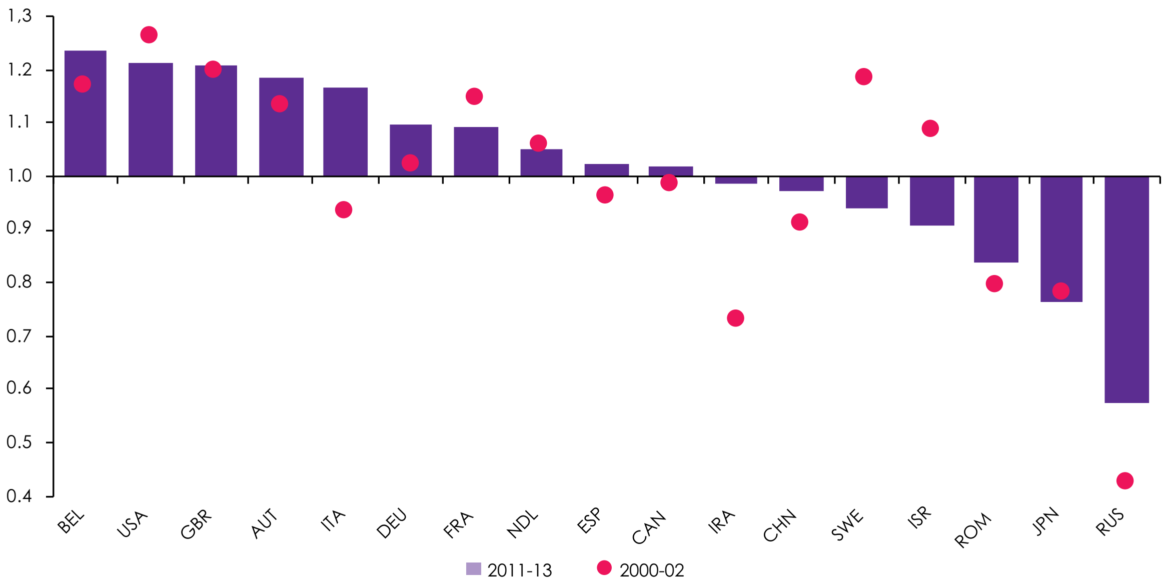
The impact of publications in the discipline of mathematics is analysed using a field normalised impact index (FNI). The analysis then focuses on the indicators identifying the top decile and centile of most highly-cited publications. Both types of indicators are calculated for the discipline as a whole, then for the different research fields. Citations are calculated using a 5-year window, taking into account the specific time frame of citations within this discipline. The methodological annex shows that, when the citation window is extended to 10 years, the impact indexes change very little after 4 years and the country rankings remain unchanged.

Impact by research field

The 5-year impact of publications within the Mathematics benchmark group varies considerably, and one of the countries have followed different trajectories since 2000. American publications still have the highest FNI, but it has fallen to a level closer to that of British, Austrian and Belgian publications, just below 1.2 (Figure 21). The Netherlands, Germany and France also have similar impact scores, around 1.1 in 2011-13. Italy's FNI rose from a level below the world average in the early 2000s (0.9) to stand 10% above that average by the early-2010s. Since 2000, France's impact has been overtaken by Austria and Italy, with Germany also catching up.

The impact scores for Sweden and Israel have shrunk considerably, slipping below the world average. In the meantime, many emerging nations have made progress even as the volume of their output has increased: examples include Iran, Romania and China. Russia has made progress, but remains the country with the lowest impact index in the Mathematics benchmark group. Japan has the lowest impact score of the research-intensive countries in the group.

Figure 21. Field-normalised impact of publications in Mathematics, 2000-13



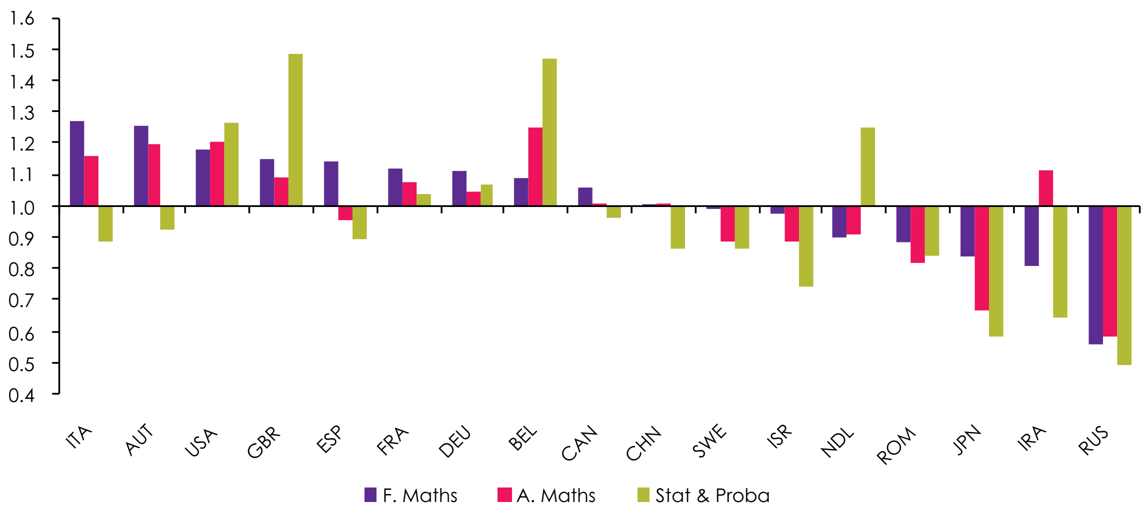
www.hceres.fr/OSTReport2019-Fig-21

Source: Computed by OST using WoS

Figure 22 shows that the impact indexes for the discipline as a whole are composed of sub-indexes for each field of research which sometimes vary dramatically. For the period 2011-13, the countries with the greatest impact in the discipline as a whole (Figure 21) had above-average impact scores for the three major fields identified in Figure 22: the United States, the United Kingdom, France, Germany and Belgium. Russia, Japan and Romania, on the other hand, recorded below-average impact scores for these three fields.

Some countries had very contrasting performance results. The United Kingdom has a number of citations per publication which is more than 50% above the world average in Statistics & Probability, with more average performances elsewhere. The Netherlands have a high FNI in Statistics & Probability, while falling below average in other fields. France has an FNI almost 15% over the world average in Fundamental Mathematics, but has lower performances in other fields.

Figure 22. Impact of publications by research fields in Mathematics, 2011-2013



www.hceres.fr/OSTReport2019-Fig-22

Source: Computed by OST using WoS

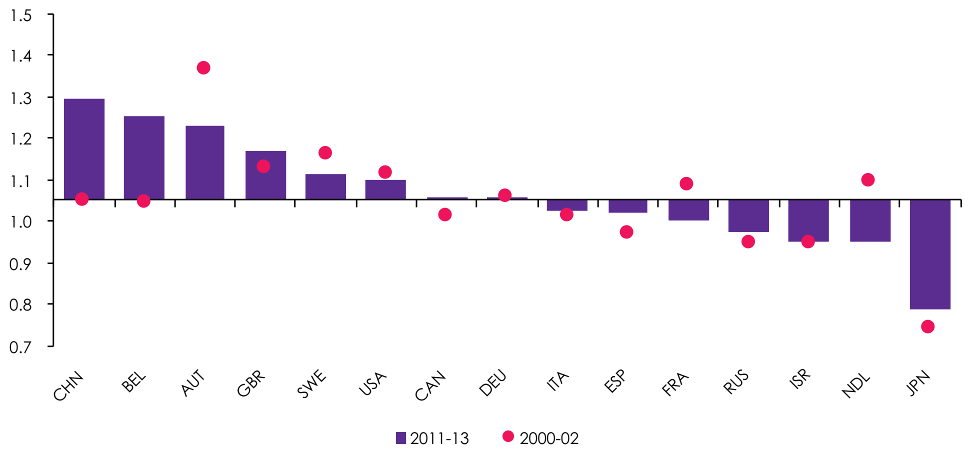
Box 5. A selective corpus of journals in mathematics: 2. Impact indexes by country

Figures B5a and b show that the impact performances of some countries vary significantly when the corpus of A* journals identified by the AustMS is examined, as opposed to the broader OST corpus. Around half of the countries in the group perform similarly in both classifications, while others have very disparate performances (Figure B5b). The impact indexes for the United States and France appear weaker, while Russia, China and Austria perform better. Figure E5b shows that this phenomenon affects both the journal-normalised impact and the impact of individual publications, but in different proportions.

The two countries with the most improved performance in the A* corpus are also those whose shares in this elite corpus differ most from their respective shares in the OST corpus: Russia and China. The hypothesis could be advanced that the publications from these two countries which are accepted by A* journals are among the very best, representing just a small portion of their total mathematical output. Meanwhile, publications from the United States and France are more numerous in the A* corpus. As such, they include examples of excellent research, but also contributions which, despite being published in A* journals, do not receive many citations. Put simply, the A* corpus is highly selective. This increases the average impact of articles published in these journals, and within the corpus those publications which have undergone the most rigorous selection (Russian publications, for example) are likely to be cited more frequently. The average impact of A* journals is indeed twice as high as the average for all mathematics journals listed in the OST database. This hypothesis would require further analysis, because the increase in FNI scores recorded by some countries could also be due to citation practices specific to the articles published in these very select journals. It might also be useful to analyse how the corpus of A* journals are distributed across the various research fields which make up the discipline.

The Netherlands' indexes are noticeably weaker in the A* corpus, and this may be a result of the composition of the corpus itself: it contains relatively few publications in the field of Statistics & Probability, but this is precisely the field in which Dutch publications score most highly on impact.

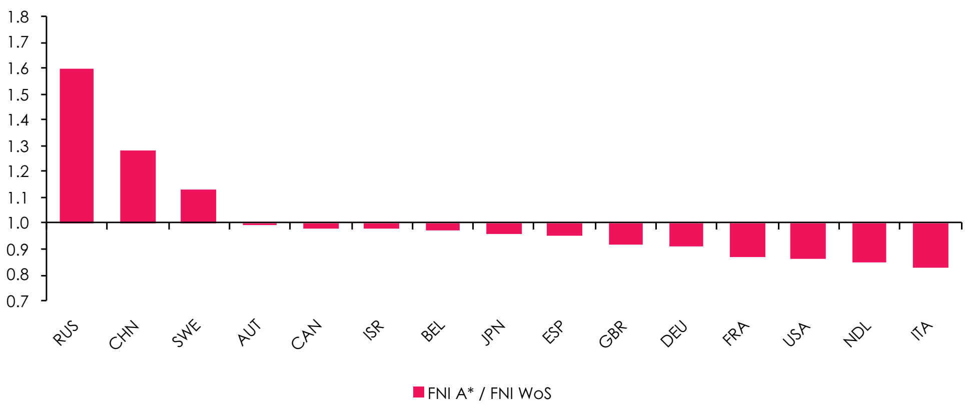
Figure B5a. FNI in mathematics, A* corpus, 2011-13



www.hceres.fr/OSTReport2019-Fig-B5a

Source: Computed by OST using WoS

Figure B5b. Impact index ratio by country, 2011-13



www.hceres.fr/OSTReport2019-Fig-B5b

Source: Computed by OST using WoS

Highly-cited publications in mathematics

The OST database contains around 6,000 publications which fall within the top 1% of most highly-cited publications in mathematics over the period 2000-13. Table 6 shows the number of publications in this top 1% produced by the countries in the Mathematics benchmark group. Together they account for more than 60% of the top 1%. The USA has a 50% higher world share of the top citation centile (29%) than of all maths publications, the reverse being true for China (14%). The US activity index in the top 1% is 1.65, and that of China is 1.23. The share of France in the top 1% is 6% for an activity index of 1.15, the respective figures for the United Kingdom being 5% and 1.70. The countries with the highest activity indices, such as Iran, Belgium, Sweden and Austria, produce a much smaller number of publications.

Table 6. Publications in mathematics among the top 1% most-cited, Mathematics benchmark countries, 2000-13

Country	Activity index in top 1%	Number of publications in top 1%[a]	Weight in top 1%
Iran	2.49	94	2.0%
Austria	1.89	35	0.8%
Sweden	1.78	29	0.6%
Belgium	1.71	38	0.8%
UK	1.70	223	4.7%
USA	1.65	1,369	28.9%
Netherlands	1.35	34	0.7%
Romania	1.24	43	0.9%
China	1.23	644	13.6%
France	1.15	284	6.0%
Israel	1.08	40	0.8%
Canada	1.05	111	2.4%
Spain	1.02	119	2.5%
Germany	0.99	192	4.1%
Italy	0.96	143	3.0%
Japan	0.61	82	1.7%
Russia	0.37	31	0.7%

a. Fractional counting, rounded to nearest whole unit.

www.hceres.fr/OSTReport2019-Tab-6

Source: Computed by OST using WoS

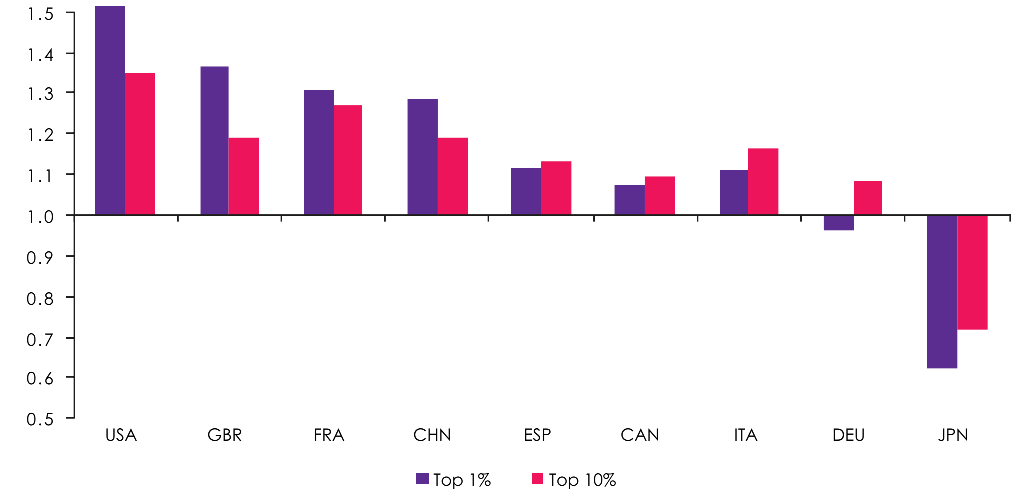
Figures 23a to 23c provide further details of activity indices in the top 10% and top 1% most-cited publications in different research fields. For each field, only those countries with more than 30 publications in the top centile are featured.

In Fundamental Mathematics, the American share of the top 1% is 50% above the world average. France also performs strongly in Fundamental Mathematics, with a share one third above the world average, close to the scores achieved by the United Kingdom and China. France also has a high activity index in the top 10%. Italy and Germany have stronger performances in the top 10% than in the top 1%. In Fundamental Mathematics, France recorded a relatively better performance for its activity in the top 1% and top 10% compared with its average FNI. By contrast, Italy's FNI performances are better in Fundamental and Applied Mathematics but the country has a lower activity index in highly-cited publications.

Iran performs very strongly in Applied Mathematics, with an activity index of 2.9 in the top 1%, while the USA scores 1.7 and China 1.1 (Figure 23b). Germany, France and Italy have activity indexes below 1 for the top 1%.

In Statistics & Probability, only the United Kingdom and the United States have more than 30 publications in the top 1%. Both countries also have high activity indices in this citation class (Figure 23c). France is one of the countries with a low proportion of highly-cited publications in Statistics & Probability. France's performance in this field, in terms of both average impact (Figure 22) and highly-cited publications, could be attributed to the fact that this classification aggregates publications in the discrete fields of statistics and probability. French research in the field of probability is widely respected, whereas statistics is a relatively young field in France compared with countries such as the Netherlands, the United Kingdom or the United States[26].

Figure 23a. Activity index in the top 10% and top 1% most-cited publications, Fundamental Mathematics[a], 2011-13

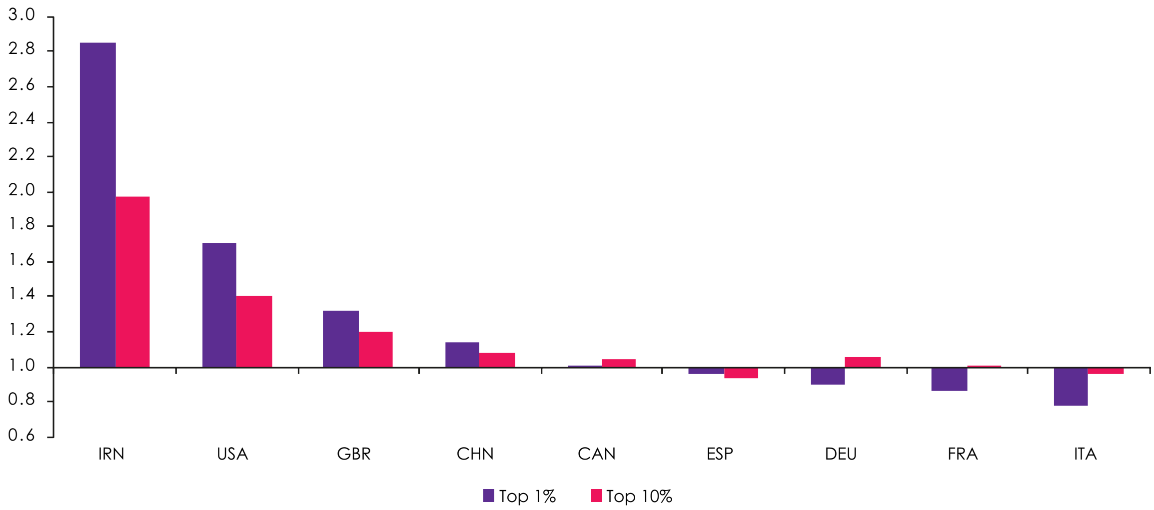


a. Countries with more than 30 publications in the top 1%.

www.hceres.fr/OSTReport2019-Fig-23a

Source: Computed by OST using WoS

Figure 23b. Activity index in the top 10% and top 1% most-cited publications, Applied Mathematics[a], 2011-13



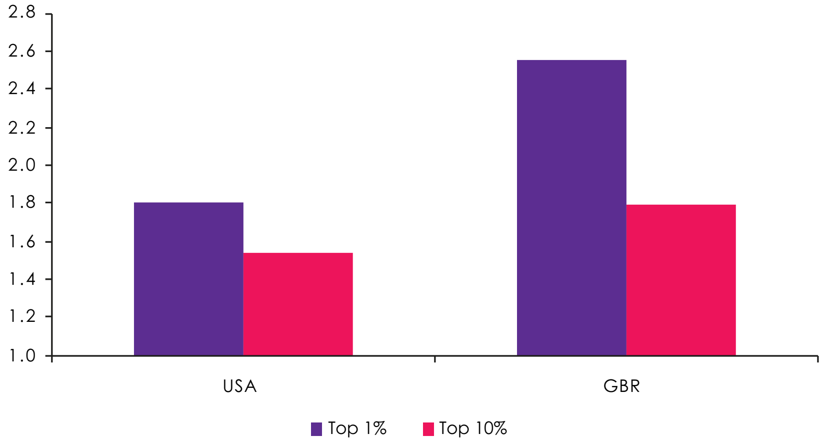
a. Countries with more than 30 publications in the top 1%.

www.hceres.fr/OSTReport2019-Fig-23b

Source: Computed by OST using WoS

26. The importance of distinguishing between statistics and probability in France was pointed out by several of the mathematicians interviewed for the purposes of this report.

Figure 23c. Activity index in the top 10% and top 1% most-cited publications, Statistics and Probability[a], 2011-13



a. Countries with more than 30 publications in the top 1%.

www.hceres.fr/OSTReport2019-Fig-23c

Source: Computed by OST using WoS

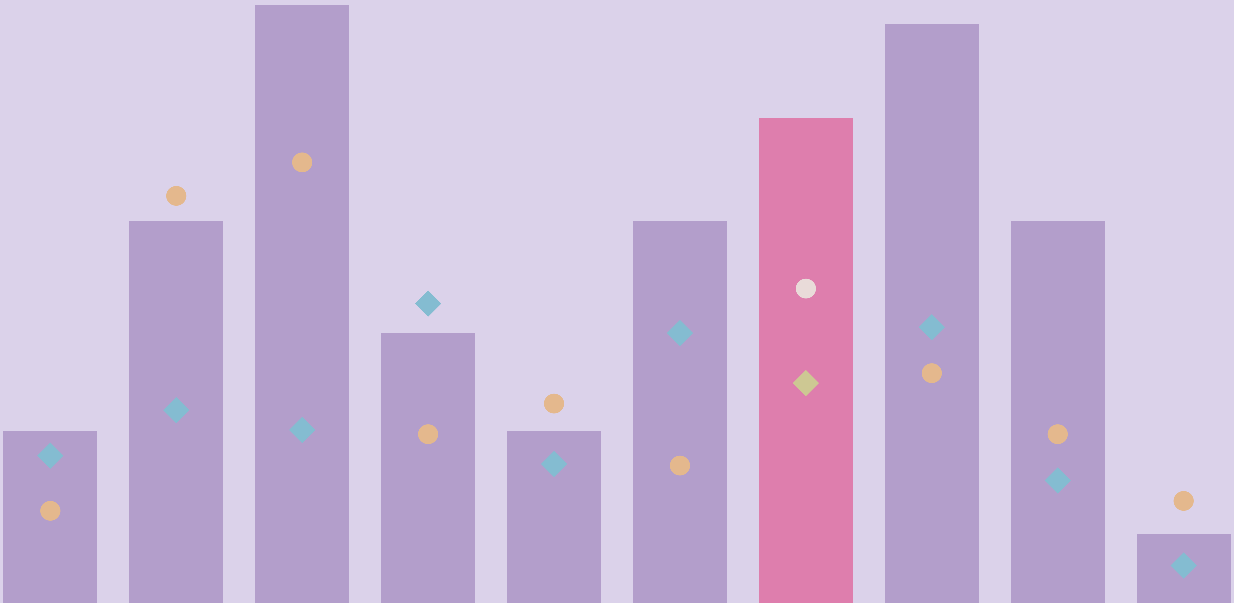
Annex 5 contains a brief analysis of national publication profiles in Statistics & Probability. Figure A5 is a map which breaks down publications in this field into 5 main clusters. It thus reveals the connections between the fundamental core of this field (Core Stat. & Proba.) and its principal fields of application. Analysis of individual country profiles shows that the UK and the USA are among the countries whose research in Statistics & Probability is largely concerned with fields of application such as economics, biology and medical sciences (Table A5). French research is noticeably more focused on Core Stat. & Proba. and less concerned with its fields of application, the latter accounting for just 29% of the total. This analysis also serves to compare the intensity of citations for each cluster (Table A5). At the global level, publications from the core of the discipline receive relatively fewer citations than those from the applied clusters. France's impact score in this discipline can be partly explained by the strong concentration (71%) of its publications in the Core Stat. & Proba. Nonetheless, the impact of French publications in all of the clusters is not high compared to the benchmark countries.

Further investigation would be required in order to clearly distinguish between publications in probability and in statistics[27]. This analysis might also test another hypothesis: that French researchers prefer to publish their probability articles in mainstream mathematical journals[28]. If this were true, some probability articles, and potentially the best of them, could be published in journals assigned to the category Fundamental Mathematics. It should nonetheless be borne in mind that, as per the OST database, France appears to be highly specialised in Statistics & Probability, which would suggest that a significant proportion of articles by French mathematicians are published in journals specialising in this field.

27. This analysis would need to be based on a more precise classification of different fields of research, such as that used by the MathScinet database, or even a textual analysis using publication metadata.

28. This hypothesis was put forward by several of the mathematicians interviewed for the purposes of this report.

4 The scientific position of France in the world and in Europe



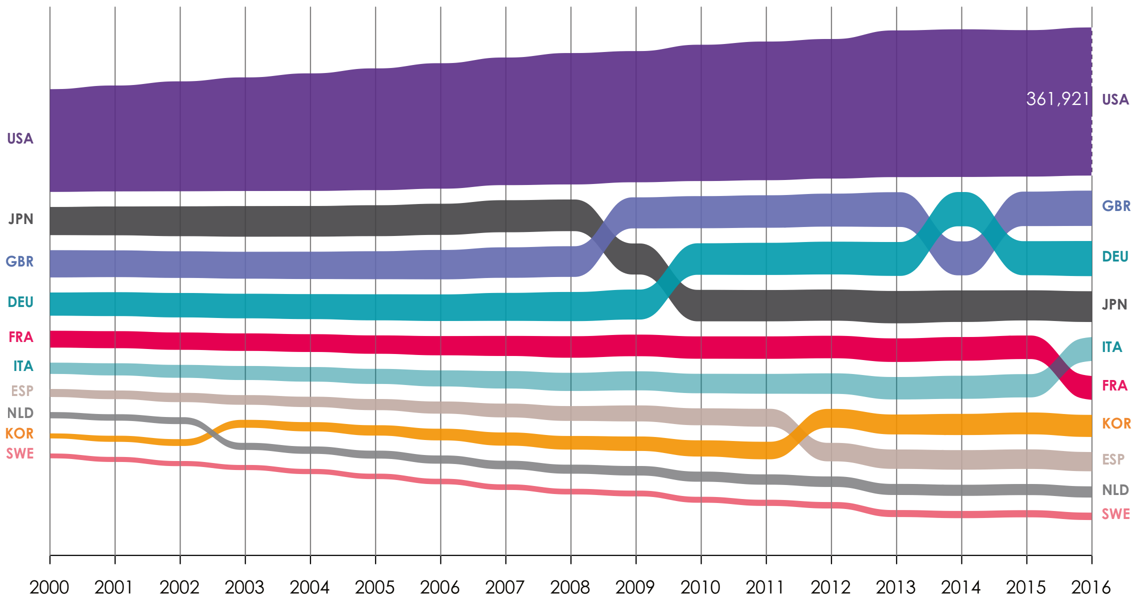
A group of countries has been selected in order to conduct detailed comparisons with France. Nine countries have been selected for their relevance to France, either in terms of their geographical proximity or their comparable performances in the fields of research and innovation. The France benchmark group comprises France and nine other countries: Germany, Italy, Japan, the Netherlands, South Korea, Spain, Sweden, the United Kingdom and the United States. After comparing publication trends and performance among the different countries in the benchmark group, this section examines the scientific position of France within the European Union. It finally looks at France's co-publications and their relative impact in different disciplines.

4.1. Publications by the France benchmark group since 2000

The countries included in the France benchmark group have all seen an increase in the volume of their scientific publications since the turn of the century, albeit at varying rates which have led to changes in the rankings. The very slow growth of Japanese publications, already discussed above, has seen Japan slip to 4th place among the benchmark group (Figure 24). Over the same period, the sustained growth in publications from South Korea has seen it overtake the Netherlands in 2003, then Spain in 2012, and get close to Italy and France by 2016. And yet, the number of Spanish publications has more than doubled over the same period. By the end of the measurement period, the two smallest producers in the group were Sweden and the Netherlands.

The annual total of French publications rose from 41,000 in 2000 to 58,000[29] in 2016, an increase of over 40% since 2000. Italy's output grew more rapidly over the same period, and now surpasses that of France.

Figure 24. Number of publications, France benchmark group, 2000-16



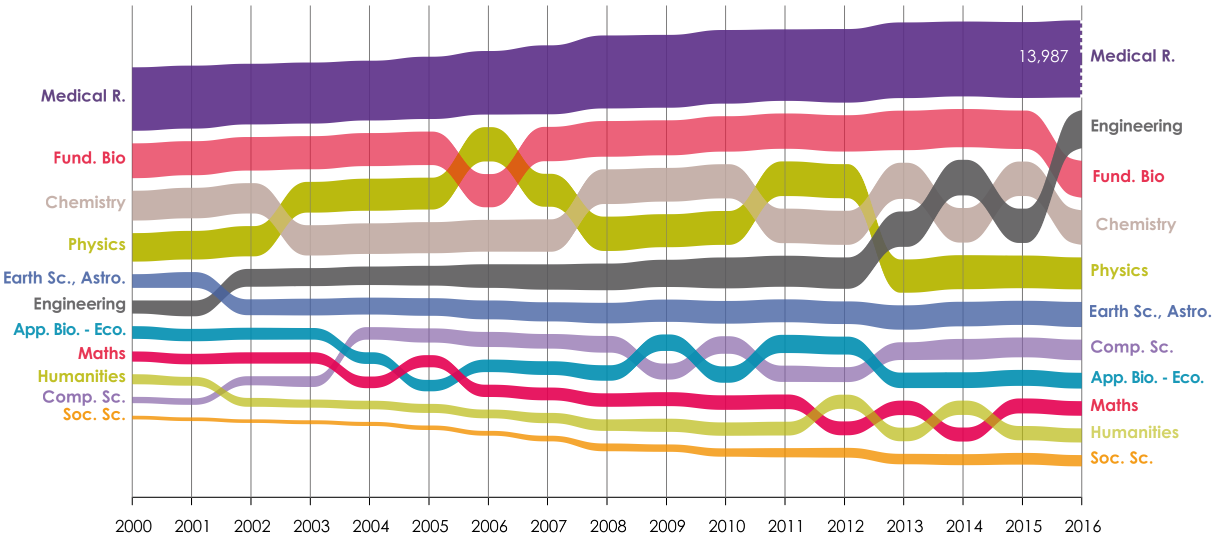
www.hceres.fr/OSTReport2019-Fig-24 — *Source: Computed by OST using WoS*

Figure 25 shows the dynamics of French publications by discipline. The number of French publications in the social sciences recorded in the OST database has more than tripled since 2000, while also doubling in computer science and engineering. As a result, the annual volume of publications in engineering now

29. Number of publications using fractional counting and rounded (90,000 in 2016 using whole counting).

outstrips that of fundamental biology and chemistry. Engineering has moved up from 6th to 2nd place in terms of the disciplines publishing the most in France. The volume of French publications in computer science has overtaken that of the humanities (2002), mathematics (2004) and applied biology-ecology (2013). Despite the large increase in the volume of publications in the social sciences, they remain the area in which France has the fewest recorded publications.

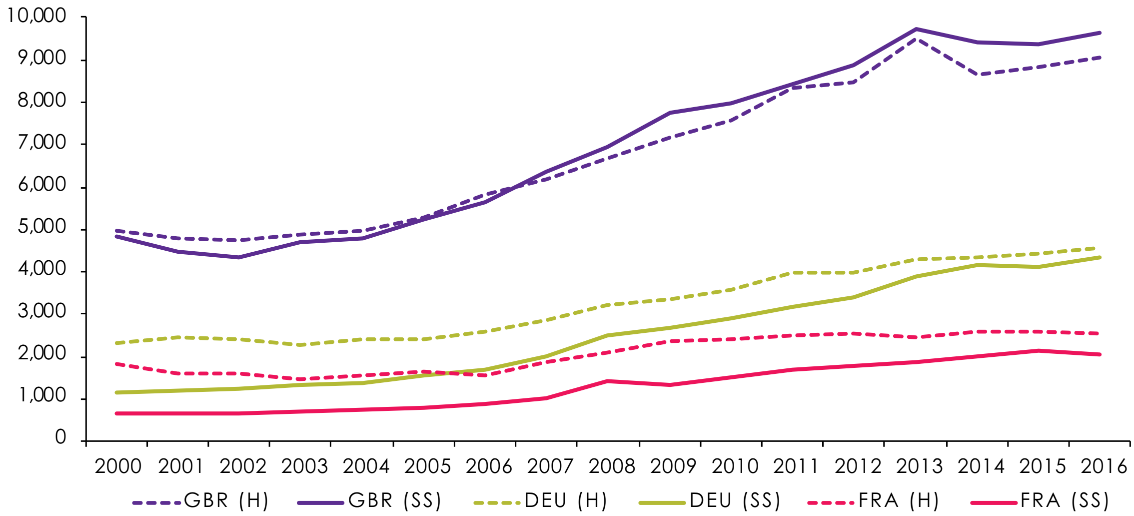
Figure 25. French scientific publications by discipline, 2000-16



www.hceres.fr/OSTReport2019-Fig-25 *Source: Computed by OST using WoS*

The sharp increase in the number of social sciences publications has also had an impact for other non-English-speaking countries. Figure 26a shows that German publications have increased nearly fourfold, while British publications have merely doubled over the same period. As a result, in 2016, Germany produces more than twice as many publications in social sciences as France.

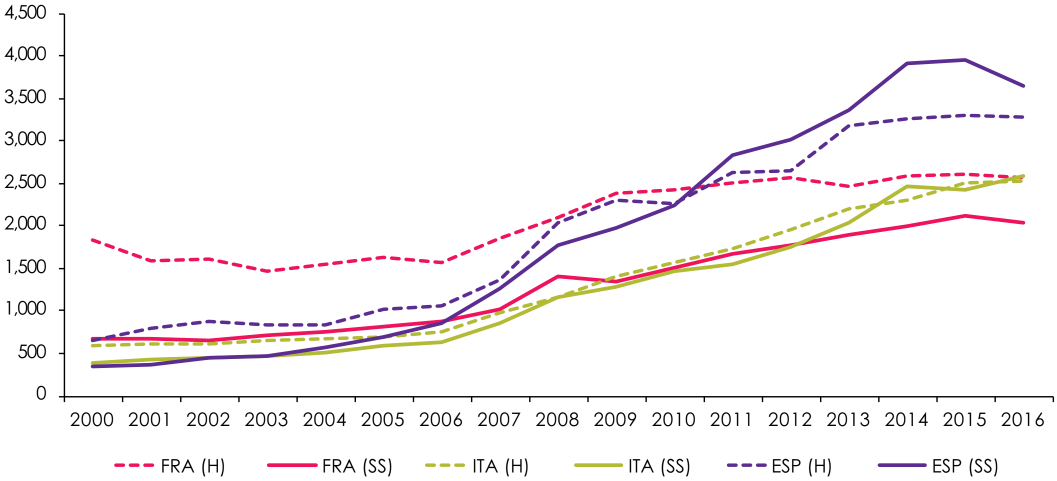
Figure 26a. Publications in social sciences and humanities, Germany, France and the UK, 2000-16



www.hceres.fr/OSTReport2019-Fig-26a *Source: Computed by OST using WoS*

Figure 26b shows that both Spain and Italy have seen a substantial increase in the number of publications in the social sciences and humanities. At the turn of the century the number of French publications in the social sciences recorded in the OST database was almost twice as large as the number of Spanish and Italian publications. Over the ensuing 16 years, the number of Spanish publications was multiplied by ten and the number of Italian publications by more than six. In 2016, both countries produced a higher number of social science publications than France.

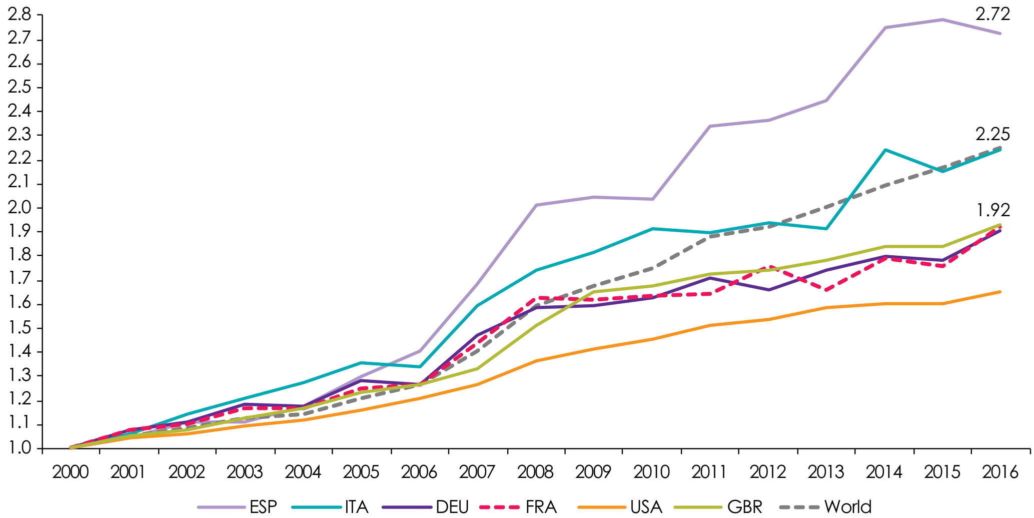
Figure 26b. Publications in social sciences and humanities, Spain, France and Italy, 2000-16



www.hceres.fr/OSTReport2019-Fig-26b Source: Computed by OST using WoS

Figure 27 shows that the dynamics of social sciences publications owes more to the inclusion of new journals in the database in Spain and Italy than in France, Germany and the United Kingdom. The United States is the country for which the increase in social sciences publications owes least to the inclusion of new journals. At the world level, two-thirds of the increase in the number of publications in the social sciences can be attributed to the addition of journals to the Web of Science database.

Figure 27. Ratio between the number of publications and the number of publications for a constant set of journals in social sciences



www.hceres.fr/OSTReport2019-Fig-27 Source: Computed by OST using WoS

Overall, the expansion of the database to include new sources has had an impact on the growing share of social sciences in total world publications (Figures 5a and b), but in relative terms French publications have received less of a boost than publications from other non-English-speaking countries. The ratio of the number of publications in social sciences for France and Germany has decreased, going from 0.57 in 2000 to 0.47 in 2006[30].

30. Based on data from figure 26a.

4.2. The scientific profile of the countries in France benchmark group

France's disciplinary profile is compared with that of the other countries in the benchmark group, with the help of specialisation indices. Disciplines from the social sciences and humanities are examined in greater detail.

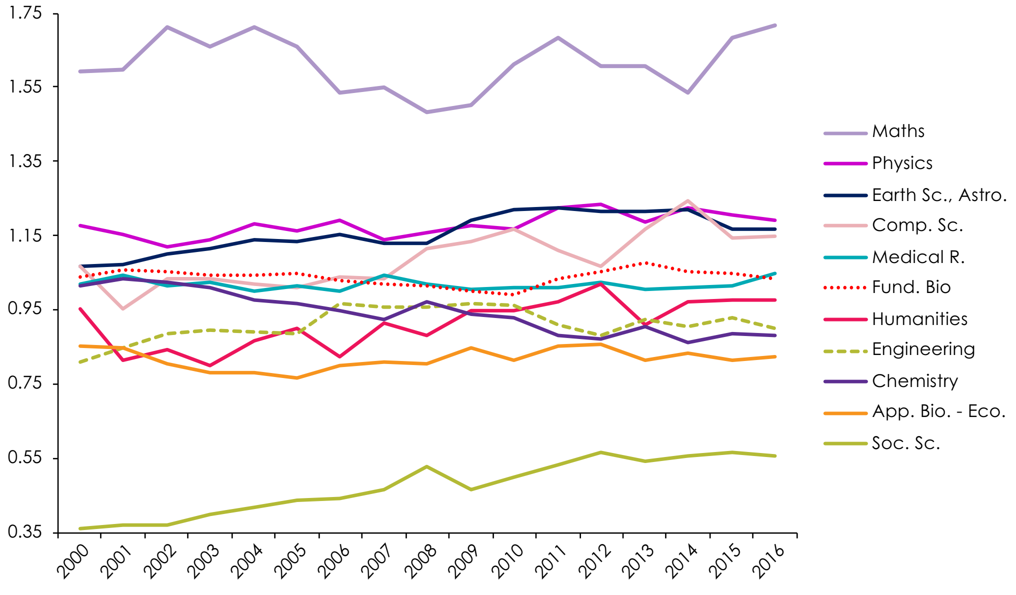
As in most parts of this report, scientific profiles are discussed on the basis of OST classification in 11 broad disciplines. Results may be compared to other reports using different classifications. The report on countries' scientific profiles published by the European commission in 2013 provides an interesting comparison since it uses a finer classification (22 fields) and Scopus data (Campbell et al. 2013). Its results with respect to the scientific profile of the countries in France benchmark group are nevertheless globally similar to what is presented below. The comparison is specifically discussed with respect to the social sciences and humanities.

4.2.1. France's specialisation in major disciplines and the impact of China's rise

Figure 28 shows France's specialisation indexes for the 11 major disciplines in OST classification between 2000 and 2016. One of the defining features of France's scientific profile is the strong specialisation in mathematics, a discipline which accounts for a share of French publications that is 70% above its average share in world publications. In the 2010s, France and Russia are the only countries among the world's top 10 producers of scientific publications to be specialised in mathematics[31]. In 2016, France also remains quite specialised in physics (1.2). The shares of medical research in fundamental biology in total French publications are close to the world averages. On the other hand, France does not appear to be specialised in engineering, chemistry or applied biology-ecology.

France's specialisation profile has evolved substantially for five disciplines. In chemistry, the specialisation index has been falling steadily since 2000 and has now dipped below 1 (0.9). In the meantime, France's specialisation index has risen sharply in the social sciences and more modestly for computer science and earth sciences-astronomy-astrophysics. These developments may be linked to the massive increase in the volume of Chinese publications (Box 6).

Figure 28. France specialisation index by discipline, 2000-16



www.hceres.fr/OSTReport2019-Fig-28

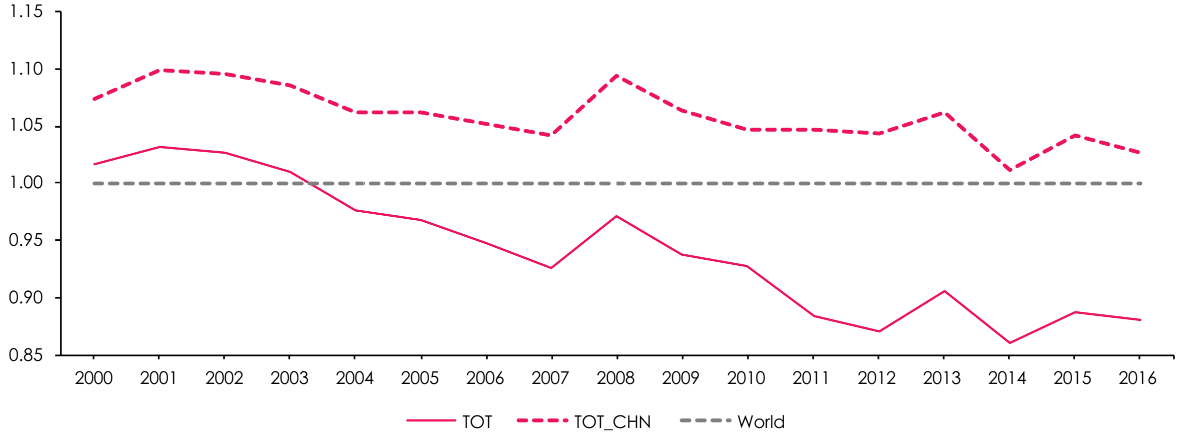
Source: Computed by OST using WoS

31. See chapter 3 above.

Box 6. The effects of China's rise on bibliometric indicators. 4. France's disciplinary profile

Simulating a world without China highlights the impact of China's rise on the disciplinary profile of other countries (Boxes 1 and 3). The surge in Chinese publications has boosted the global share of those disciplines in which China is specialised: chemistry, physics, computer science and engineering. This mechanically drives down the specialisation index of those countries which have not seen such a dramatic expansion in their output in these disciplines. Figure B6a highlights the growing gap between the actual French specialisation index for chemistry and how that specialisation index would look in a world without China. In 2016, France's specialisation index in chemistry was 17% weaker than it would have been in a world without China. In the social sciences, where the number of French publications has increased considerably (see Figures 25 and 26a), the influence of China can still be felt because China is not at all specialised in this discipline. Figure B6b shows that France's specialisation index for social sciences in 2016 was 9% higher than it would have been in a world without China.

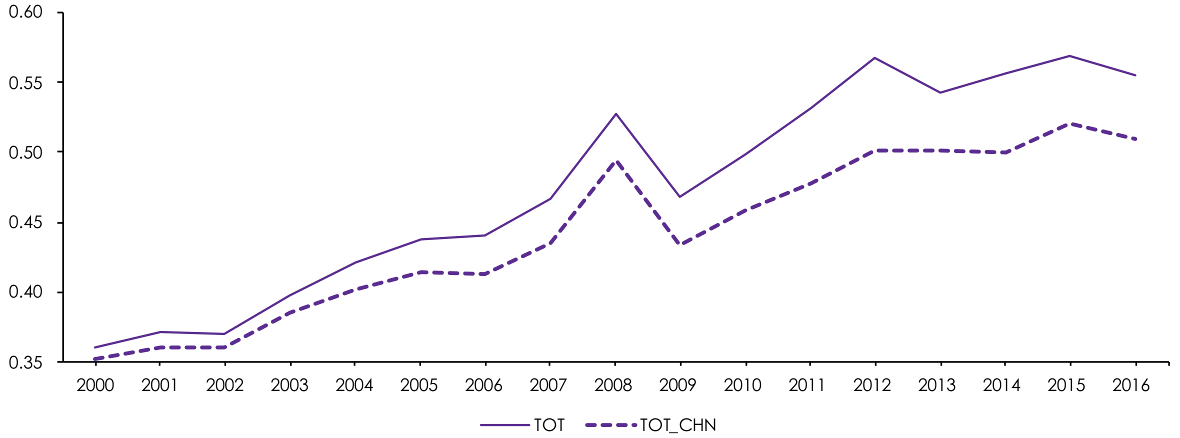
Figure B6a. Specialisation Index of France in chemistry: world and world without China, 2000-16



www.hceres.fr/OSTReport2019-Fig-B6a

Source: Computed by OST using WoS

Figure B6b. Specialisation Index of France in social sciences: world and world without China, 2000-16



The world average is not shown since France has an index far below 1.

www.hceres.fr/OSTReport2019-Fig-B6b

Source: Computed by OST using WoS

Due to the growing importance of computer science in France's scientific profile, three disciplines now account for a share of French publications almost 20% greater than their share in total world publications: physics, earth sciences-astronomy-astrophysics and computer science. France is still not specialised in social sciences, with an index 40% below the world average, making it the discipline in which France appears to be least specialised. There are notably fewer listed publications in social sciences than in the humanities (Figures 26 a and b), whose share in total French publications was close to the world average in 2016.

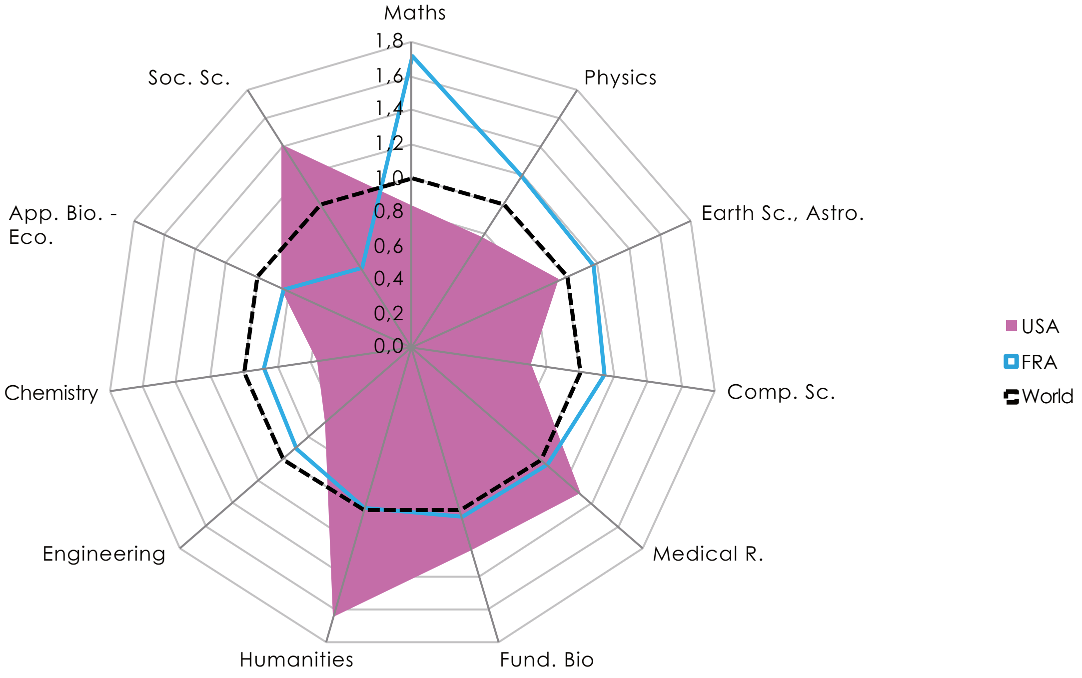
4.2.2. The disciplinary profile of France and the benchmark countries

Figures 29a to 29e compare the disciplinary profiles of the countries that make up the France benchmark group. In these figures, the disciplines are arranged in decreasing order of France's specialisation index, with mathematics in first place and social sciences last.

The disciplinary profile of France is very different from that of the United States (Figure 29a). France's specialisation index in mathematics is double the American index (0.8). Nor does the USA appear to be specialised in physics, earth science-astronomy-astrophysics or computer science, unlike France. In the latter discipline, American specialisation has waned (NSF 2016).

The USA is specialised in fundamental biology and medical research, and highly specialised in social sciences and humanities. As shown below in the section devoted to these disciplines, in the classification used in this report, the humanities include psychology in which the USA is strongly specialised[32].

Figure 29a. Scientific profiles: France and United States, 2016



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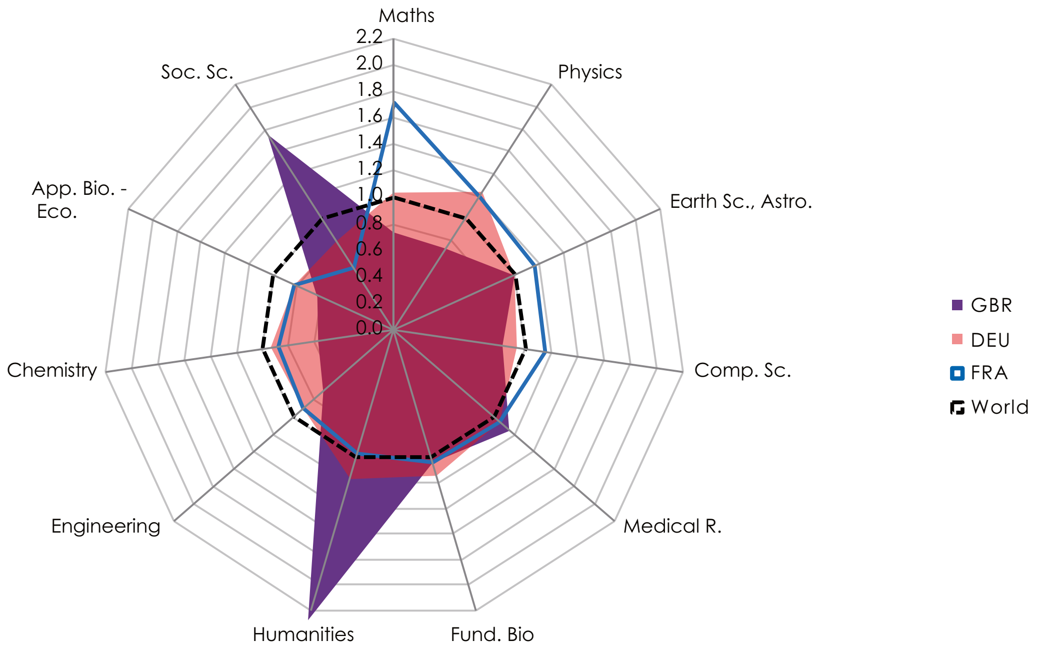
Source: Computed by OST using WoS

The United Kingdom is even more heavily specialised than the United States in social sciences, and especially in the humanities (Figure 29b). The UK is also strongly specialised in psychology. The UK specialisation index is slightly weaker in medical research, but remains higher than that of France and Germany. Overall, Germany has a balanced scientific profile: its highest specialisation index is for physics, at just over 1.2. Germany can be considered modestly specialised in fundamental biology, humanities and chemistry, with indexes of between 1 and 1.2.

32. Based on results in Campbell et al. (2013), using a classification in 22 fields that include "Psychology and Cognitive sciences".

Italy also has a fairly balanced profile (Figure 29c). Italy's highest specialisation index is for medical research, at over 1.3, with scores of 1.2 in mathematics and earth sciences-astronomy-astrophysics. Spain's profile is more heterogeneous, with a specialisation index of over 1.5 in the humanities. The Spanish specialisation index in applied biology-ecology and in social sciences is 1.2. Conversely, Spain is not specialised in physics and chemistry.

Figure 29b. Scientific profiles: France, Germany and United Kingdom, 2016



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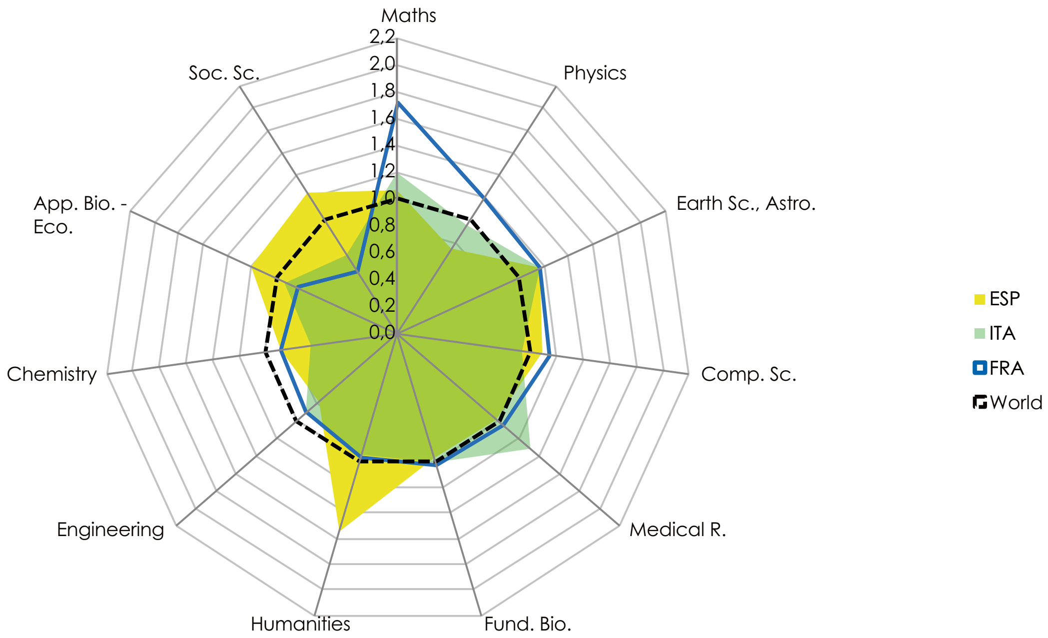
Source: Computed by OST using WoS

Figure 29c. Scientific profiles: France, Spain and Italy, 2016



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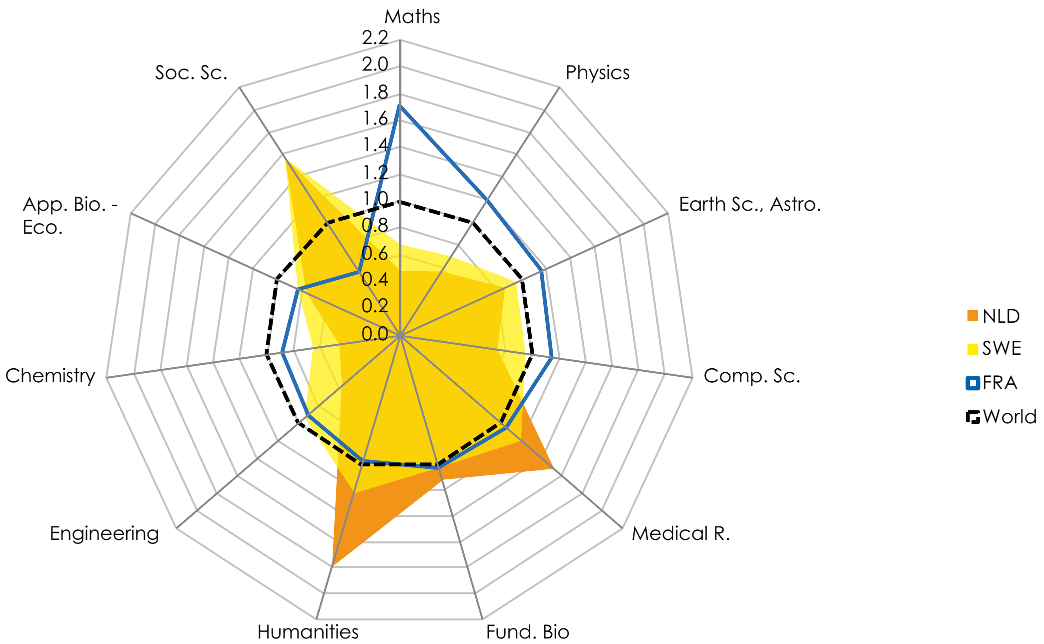
Source: Computed by OST using WoS

The Netherlands and Sweden have similar disciplinary profiles, but with greater contrasts for the Netherlands (Figure 29d). Both countries are heavily specialised in the social sciences, while the Dutch are also highly specialised in the humanities and specialised in medical research. Their very high index score (almost 1.8) in the humanities can be partly explained by the Netherlands' strong specialisation in psychology[33]. Meanwhile, the country has low indexes in chemistry and mathematics.

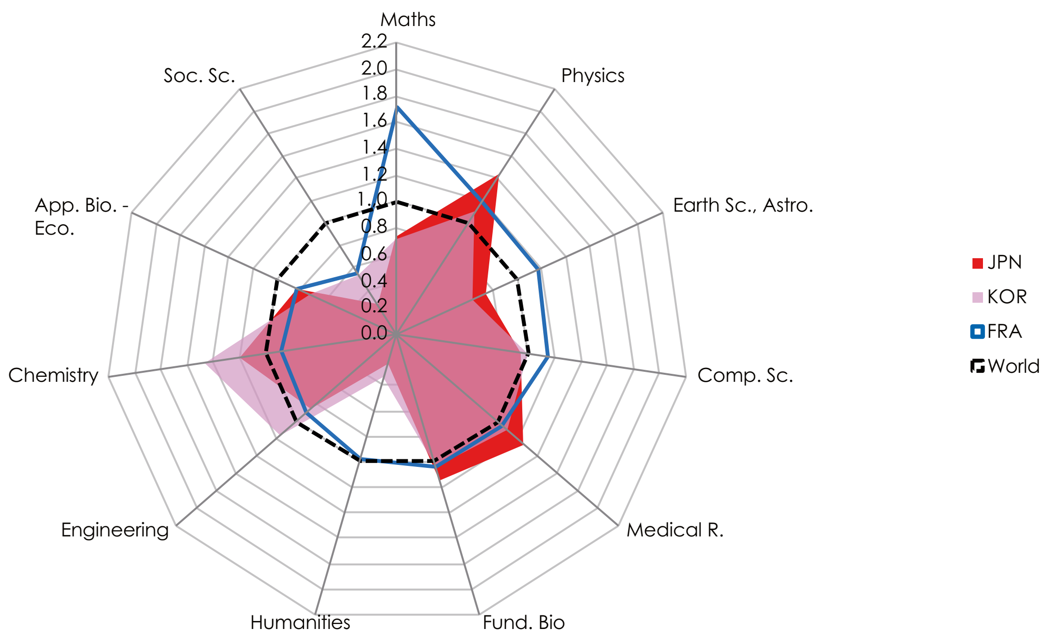
Figure 29d. Scientific profiles: France, Netherlands and Sweden, 2016



www.hceres.fr/OSTReport2019-Fig-29d

Source: Computed by OST using WoS

Figure 29e. Scientific profiles: France, Japan and South Korea, 2016



www.hceres.fr/OSTReport2019-Fig-29e

Source: Computed by OST using WoS

33. As reported by Campbell et al. (2013).

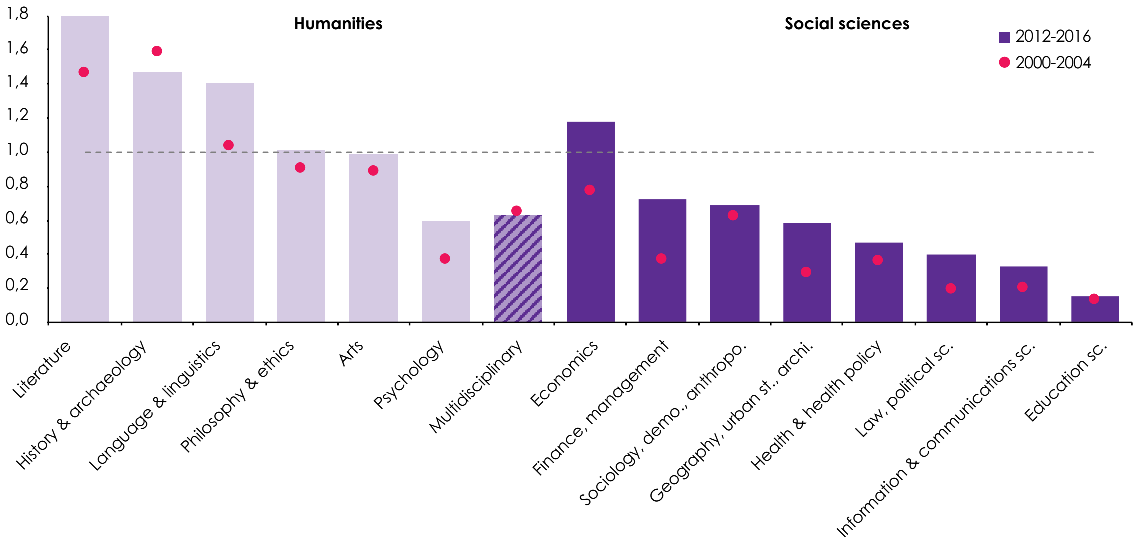
The scientific profiles of Japan and South Korea are relatively close, albeit with a few differences. Both countries have a very weak presence in the humanities, and are not specialised in earth sciences-astronomy-astrophysics, mathematics or social sciences. However, both countries are specialised in chemistry. South Korea is specialised in engineering, while Japan is moderately specialised in medical research and fundamental biology.

4.2.3. Evolution of French specialisation in social sciences and the humanities

Figure 30 details the evolution of France's specialisation in the different fields of the social sciences and humanities[34]. The figure paints a varied picture, as France is clearly specialised in certain fields and not at all in others.

Overall, France's specialisation in the humanities has increased a little. It has increased substantially in literary studies, linguistics and arts, while in history and archaeology, the specialisation index decreases slightly. Of the humanities, psychology is the field in which France's specialisation index is lowest, although it has doubled since 2000. It is worth noting that publications in this field largely take the form of articles in peer-reviewed journals. In 2016, psychology accounts for 27% of French publications in the humanities, while the share of the discipline is higher in all the benchmark countries, including the Netherlands (50%), Germany (44%) or the United States (42%). By the same token, France's relative weak specialisation index in the humanities here may be related to its relatively low proportion of psychology publications[35].

Figure 30. Evolution of French specialisation in social sciences and humanities, 2000-16



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Source: Computed by OST using WoS

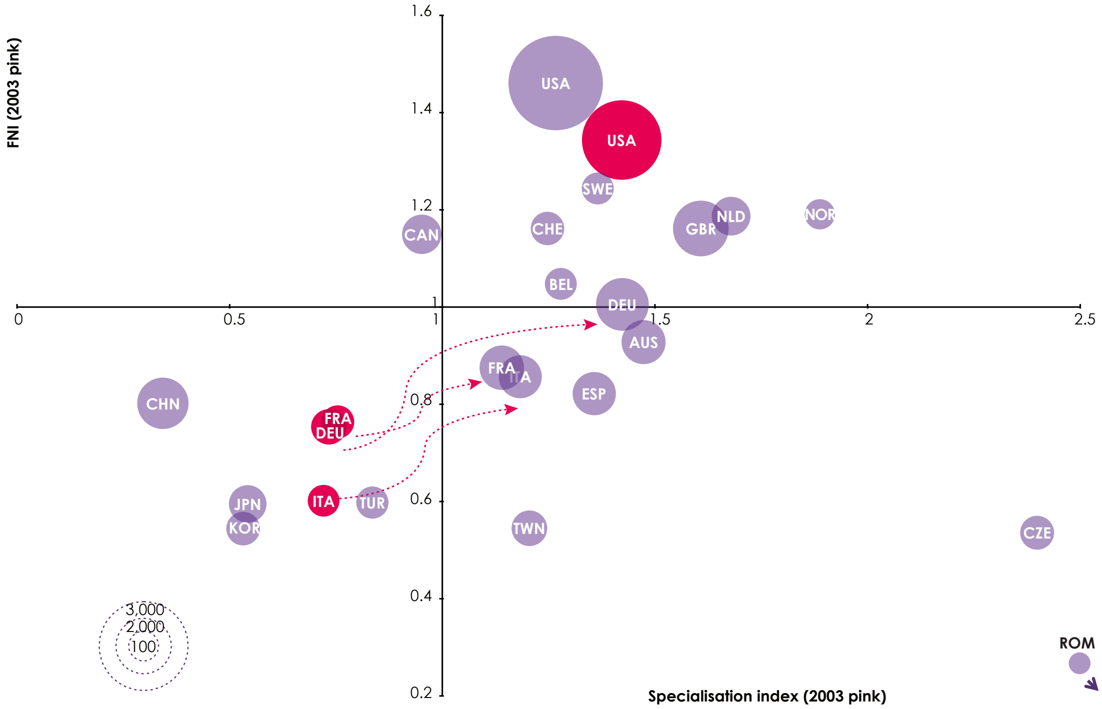
Figure 30 shows also that France's specialisation index has risen by between 50 and 100% in four fields within social sciences: economics, finance and management, geography, urban studies and architecture, law & political science. In economics, France has an index of 1.1 in 2012-16.

Figure 31 shows the specialisation and impact indexes for the world's top 20 producers of publications in economics. As compared to the early 2000s, in 2014, France has become specialised in economics with an index of 1.14. A number of European countries, some of them non-English-speaking, are even more specialised. The most specialised in this field are Romania, the Czech Republic and Norway. The Netherlands and the UK are also quite specialised in economics.

34. These groupings were created based on the fields of research listed in the Web of Science database.

35. The panels of the European Research Council have been used to generate a different classification. France is specialized in SH5, Cultures and cultural production and more strongly in SH6, Study of human past. It is not specialized in SH4, Human mind and complexity that includes psychology, philosophy and linguistics.

Figure 31. Specialisation and impact in economics, top 20 producers, 2014



www.hceres.fr/OSTReport2019-Fig-31

Source: Computed by OST using WoS

Of the countries specialising in economics, the United States is by far the largest producing country, and the country whose publications have the greatest academic impact. The USA's specialisation index has stagnated, but the academic impact of American publications has increased. A number of European nations also have impact indexes which surpass the world average, particularly Sweden, Switzerland, the United Kingdom, Norway and the Netherlands.

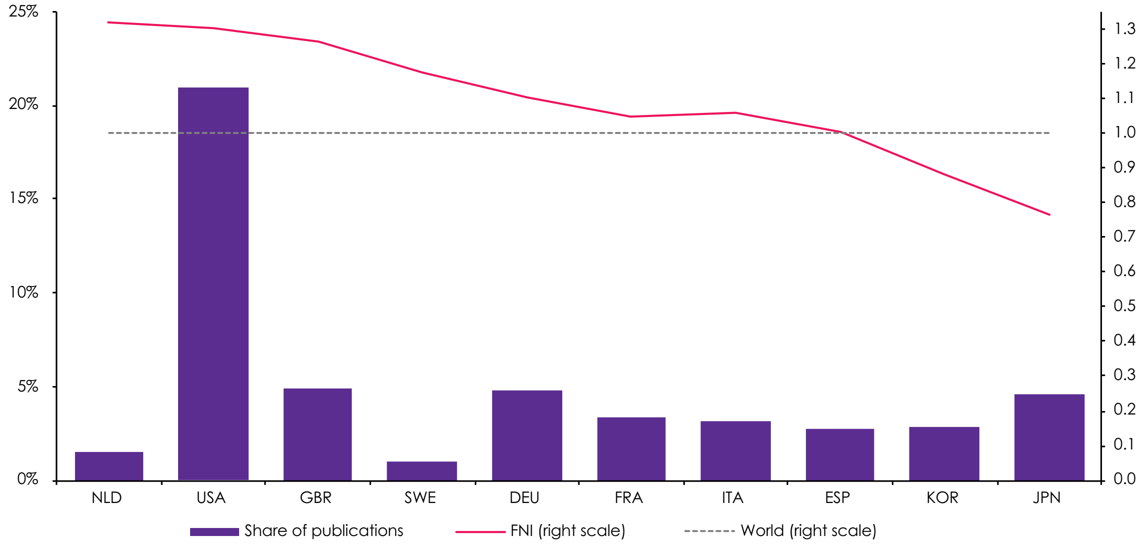
Between 2003 and 2014, not only did France become specialised in economics, the impact of its publications increased too. This impact remains below the world average, but close to the score recorded by Italy. Italy and Germany have seen stronger increases in their specialisation and impact.

4.3. Scientific impact of the publications from the France benchmark group

Within the France benchmark group, only Sweden is not among the world's top 20 producers of scientific publications (21st in 2016). Figure 32 presents a simplified version of Figure 6 (Section 2) with Sweden added in. Within the France benchmark group, Sweden ranks 4th in terms of the academic impact, behind the Netherlands, the United States and the United Kingdom. These three countries have a number of citations per publication which is 30% above the world average. Figure 32 illustrates the proximity between France and Italy, in terms of both the volume and the impact of their scientific publications, which is almost 10% above the world average[36]. Germany publishes more and boasts a slightly higher impact index, while Spain publishes less and has an impact index on a par with the world average. In the benchmark group, only Japan and South Korea have impact index below the world average.

36. For 2000-11, Campbell et al. (2013), drawing upon Scopus, calculated a very close average impact for both countries.

Figure 32. World share of publications and impact: France benchmark group, 2012-14



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Source: Computed by OST using WoS

Figures 33a to 33e compare and contrast two indicators: the field normalised citation impact of publications (FNI) and the field normalised impact of the journals (JNI)* in which they appear, for the countries in the France benchmark group and for 11 disciplines. All in all, these five figures reveal a positive correlation between the impact of journals and the impact of the articles they publish, with exceptions for a number of cases. They also show that the impact of publications measured at country level may result either from comparable performances across different disciplines, as is the case of the United States, or from varied performances across different disciplines, as with France.

Figure 33a compares France and Germany, and the subsequent figures compare other countries from the benchmark group in pairs. In order to make these figures easier to read, the countries are grouped together based on the average impact of all of their publications. This allows the use of different scales from one figure to the next. For example, the FNI for French publications varies from 0.6 to 1.4 depending on the discipline, whereas for the United States the range is much smaller: 1.2 to 1.5. Japan's impact scores range from 0.5 to 0.9, while Dutch scores range from 1 to 1.5.

Figure 33a shows that the slightly superior impact of German publications compared with French output holds true across most disciplines. The impact of French publications is superior in applied biology-ecology, engineering and computer science. But the impact of French publications lags well behind that of German publications in the humanities, a discipline in which Germany is specialised. The same is true of the social sciences. In other disciplines, the impact of German publications is either slightly higher than or equal to that of French publications. German publications tend to attract slightly more citations than the average for the journals in which they appear, with the exception of chemistry.

Figure 33b shows that the great similarity between the overall impact indexes for French and Italian publications (Figure 32) actually conceals contrasting situations at individual discipline level. The respective impact indexes are closely aligned in medical research (1), physics and chemistry (1.1). France comes out on top in applied biology-ecology and earth sciences-astronomy-astrophysics, while Italy is ahead in engineering, mathematics, computer science, social sciences and humanities. Italian publications are more likely than French publications to attract more citations than the average for the journals in which they appear.

Spanish publications in the field of engineering have a lower impact than Italian publications (Figure 33b), but score more highly than French publications (Figure 33a). The impact of Spanish publications is close to that of French publications in chemistry and physics, but lags below in social sciences and medical research.

The impacts for British and American journals and publications are above the world average in all disciplines (Figure 33c). Furthermore, British and American publications tend to attract more citations than the average for the journals in which they appear. The FNI for British publications exceeds that for

French publications in all disciplines (Figures 33a and 33c). The gap is most pronounced in the humanities, social sciences and computer science, and less so in chemistry.

American publications also tend to be more cited than French publications in all disciplines (Figure 33c). The gap is greatest in the four disciplines in which the USA is most specialised: humanities, social sciences, medical research and fundamental biology. Generally speaking, American publications appear in journals which are cited 20 to 40% more than the world average, with the exception of chemistry. In this discipline, the average impact of the journals in which American researchers publish is 60% above the world average, and the impact of their publications is 50% above average.

The impact of Dutch publications surpasses that of Swedish publications, on average and for individual disciplines (Figure 33d). For example, the FNI for Swedish publications in physics is just over 1.1, while the Dutch score is 1.4. The disciplinary scores for both countries are higher than those for France. France's greatest impact is in applied biology-ecology: Sweden has an equivalent FNI, but the Dutch score more highly. The lowest impact scores recorded by the Netherlands and Sweden are close to 1, in computer science and mathematics respectively. France's lowest impact score is just over 0.6, in the humanities (Figure 33a). The impact index for mathematics is around 1 for Sweden and the Netherlands, making it the weakest discipline for both countries[37].

Unlike those two countries, Japan and South Korea both have impact scores inferior to the French scores across all disciplines (Figure 33e). These impact scores range from 0.5 for Japanese computer science publications to just over 1 for South Korean publications on chemistry and engineering. Both countries have relatively weak impact scores in their disciplines of specialisation, engineering for South Korea and physics for Japan. In chemistry, like all of the countries included in the France benchmark group with the exception of South Korea, the impact of Japanese publications is well below the average impact for the journals in which these publications appear. On a more general level, of all the countries in the benchmark group, Japan and to a lesser extent South Korea are the countries whose publications are more likely to receive fewer citations than the average for the journals in which they appear.

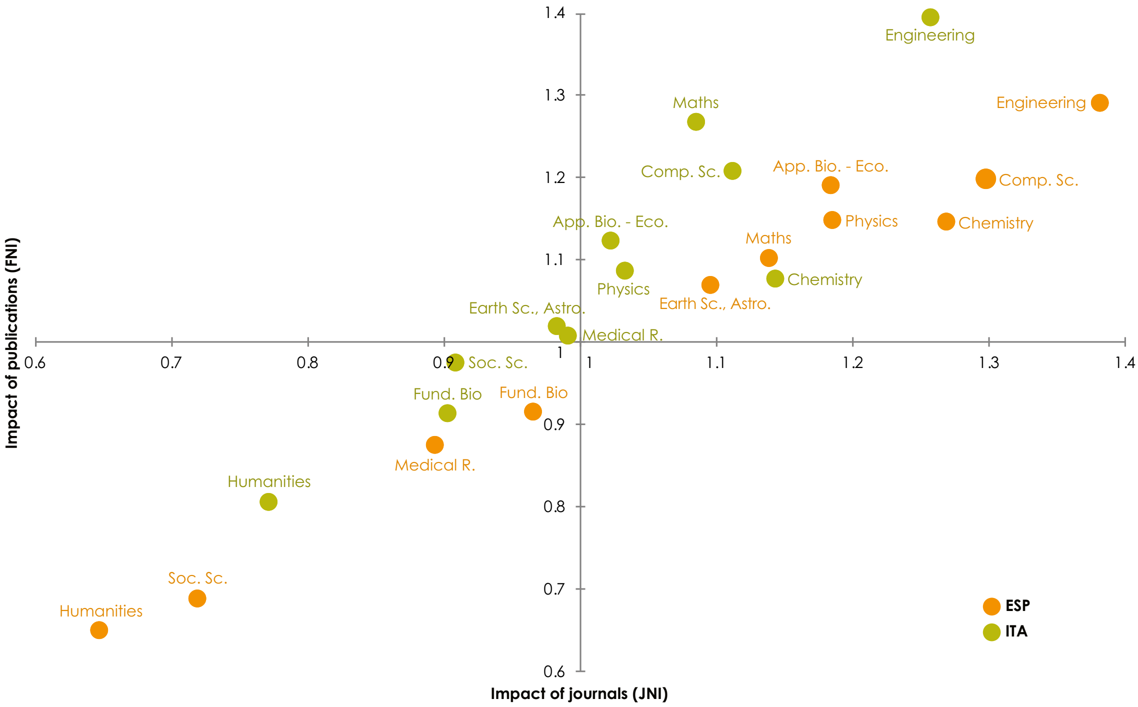
Figure 33a. Normalised citation impact of publications and journals: Germany and France, 2012-14

www.hceres.fr/OSTReport2019-Fig-33

Source: Computed by OST using WoS

37. This report uses 3-year citation window, except in the section devoted to mathematics where a 5-year citation window is used (see the methodological part). For the Netherlands and Sweden, the FNI in mathematics is the same (Figures 21 and 33d).

Figure 33b. Normalised citation impact of publications and journals: Spain and Italy, 2012-14



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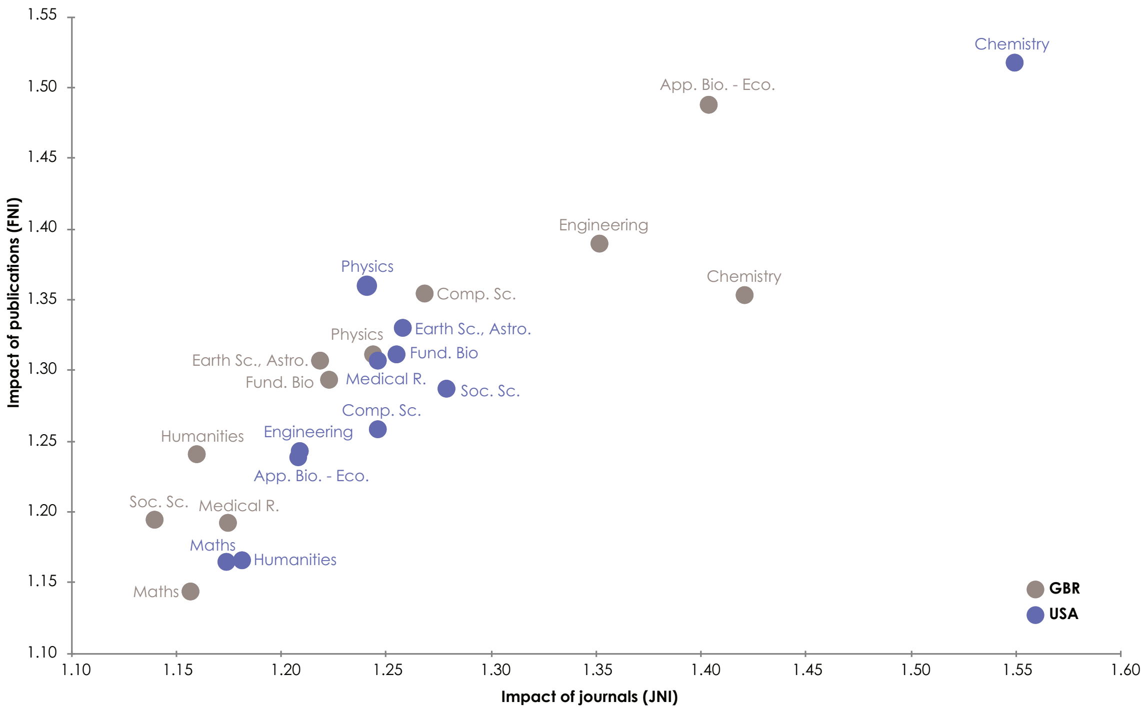
Source: Computed by OST using WoS

Figure 33c. Normalised citation impact of publications and journals: United States and United Kingdom, 2012-14



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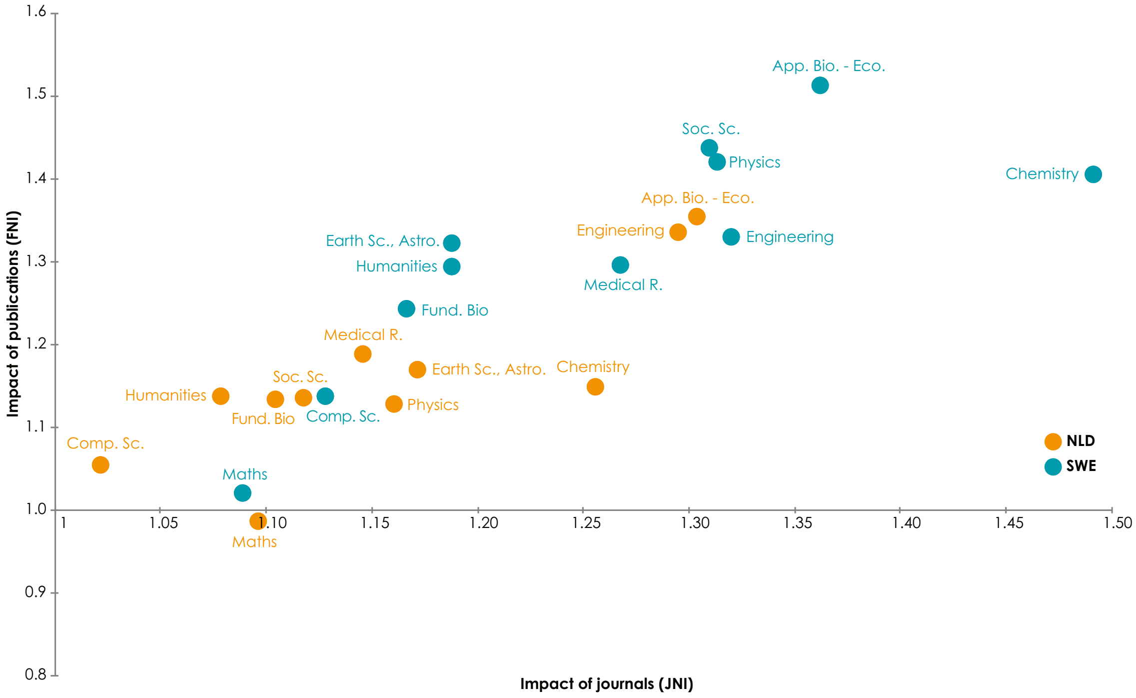
Source: Computed by OST using WoS

Figure 33d. Normalised citation impact of publications and journals: Netherlands and Sweden, 2012-14



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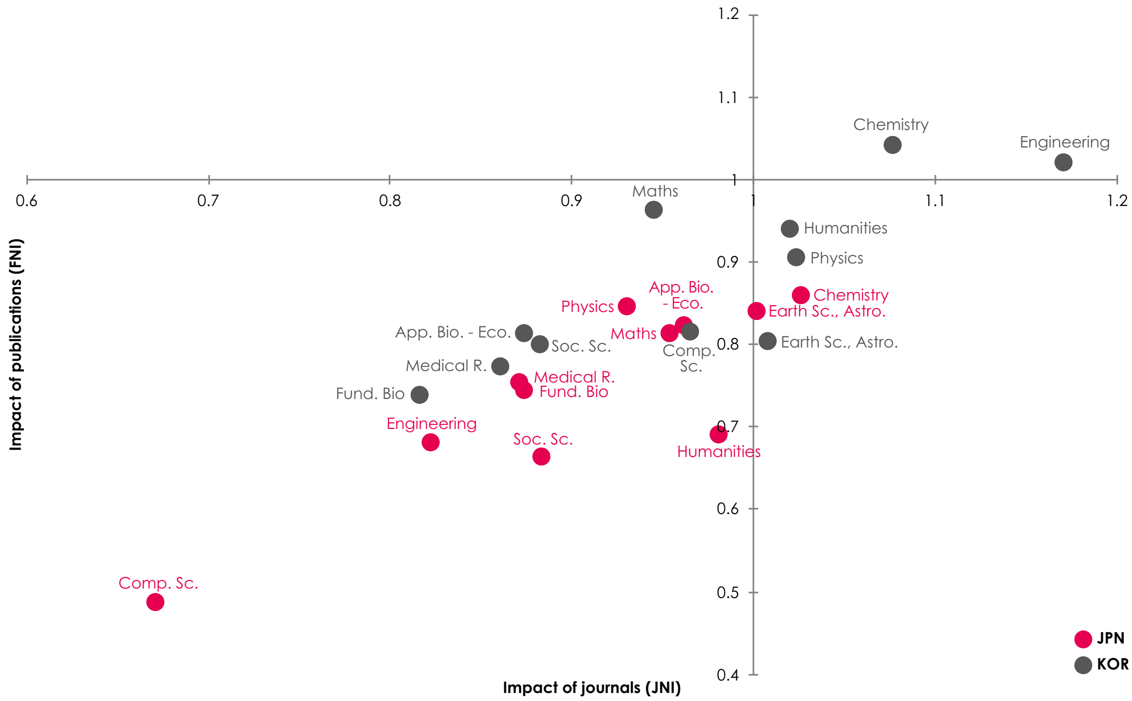
Source: Computed by OST using WoS

Figure 33e. Normalised citation impact of publications and journals: South Korea and Japan, 2012-14



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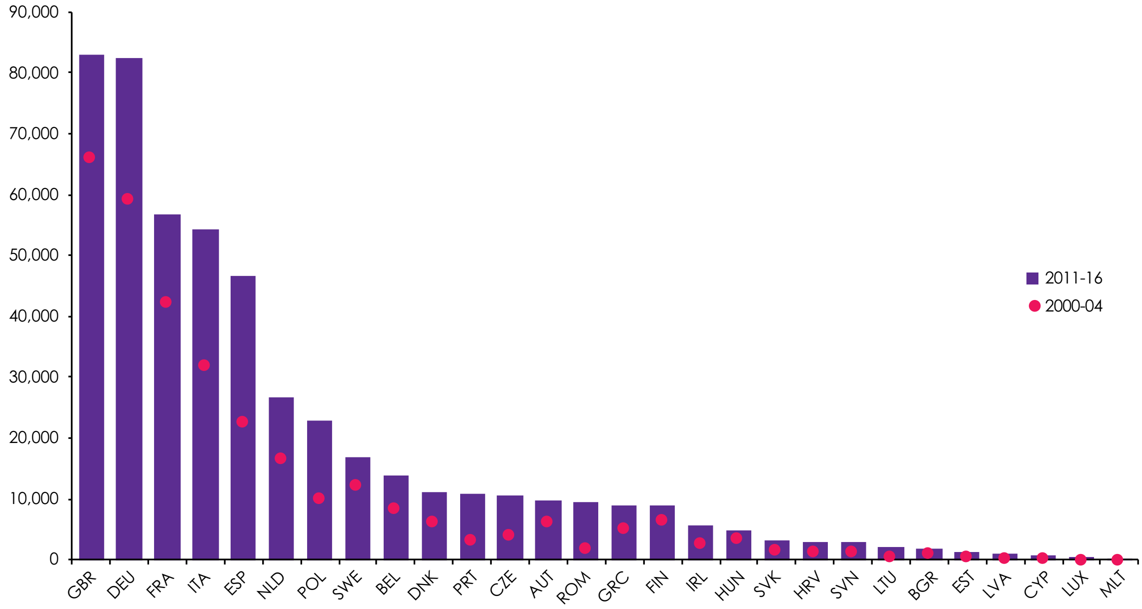
Source: Computed by OST using WoS

4.4. The scientific position of France within the European Union

Within the EU, the relative positions of the top 10 producers of scientific publications have changed (Figure 34). The UK remains the largest publisher, but the total number of British publications is now only just greater than the total for Germany, which has seen more dynamic growth. Italy has seen much more rapid growth in number of recorded publications than France, just edging past France in 2016. Spain (5th) and Poland (7th) have also seen strong growth, and in 2016 Poland produced more publications than Sweden.

Figure 34. Evolution of the number of publications of EU countries, 2000-16

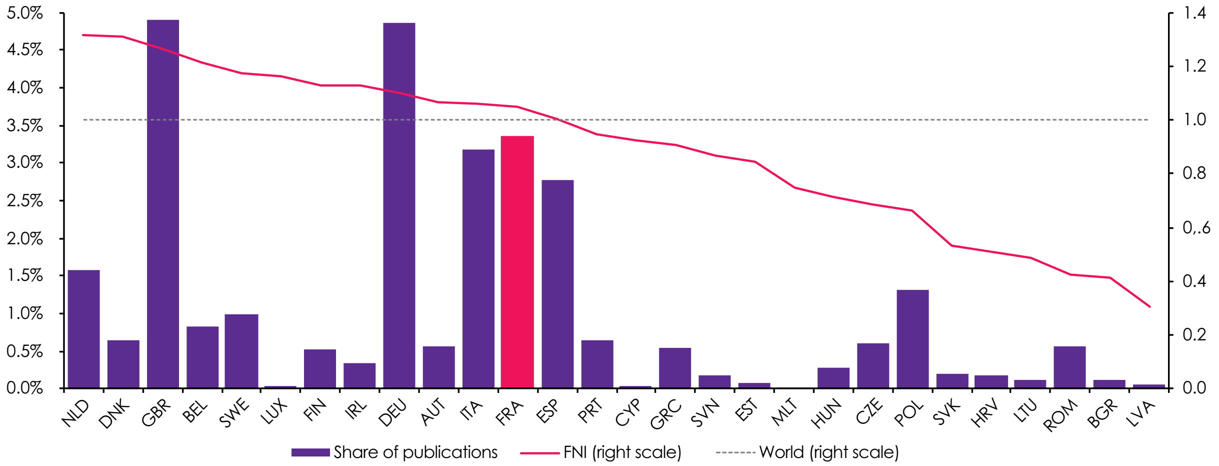


www.hceres.fr/OSTReport2019-Fig-34 Source: Computed by OST using WoS

For publications (Figure 35) issued in 2012-14, the EU countries with an FNI above 1 are high income research intensive countries. The Netherlands, Denmark, the UK and Belgium have an FNI above 1.2, Sweden, Luxembourg, Finland, Ireland and Germany above 1.1. The index is between 1 and 1.1 for Austria, Italy, France and Spain.

Rankings within the EU are very similar for the intensity of top 10% most-cited publications (Figure 36). For 2014 publications, the Netherlands, Denmark and the UK have an activity index in the top 10% most-cited publications 40% above the world average. Among EU countries, they are followed by Belgium, the performance of which is more than 25% above the world average. The activity index of Luxembourg, Sweden, Ireland, Germany, Finland and Austria is between 10 and 20% above the world average. France's performance is close to the EU average at 4% above the world average. It has improved its performance since 2000, but to a lesser extent than several other European countries, including Ireland, Sweden, Belgium, Spain or Italy. For 2014 publications, Italy has a slightly higher activity index.

Figure 35. World share of publications and impact: EU countries, 2012-14



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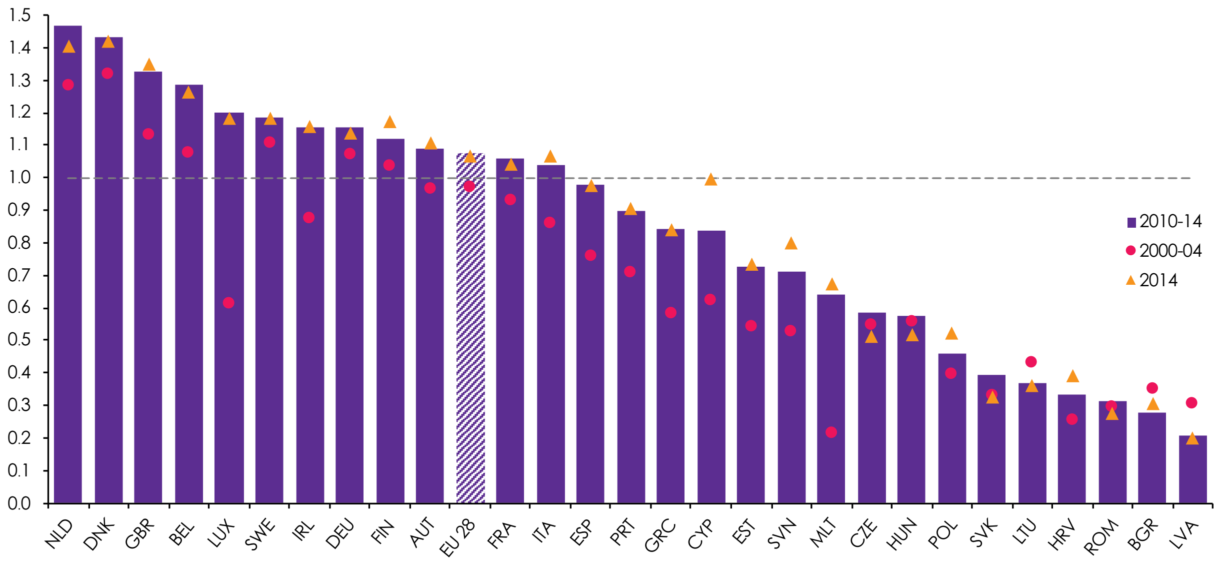
Source: Computed by OST using WoS

Figure 36. Activity index in the top 10% most-cited publications, EU and member countries



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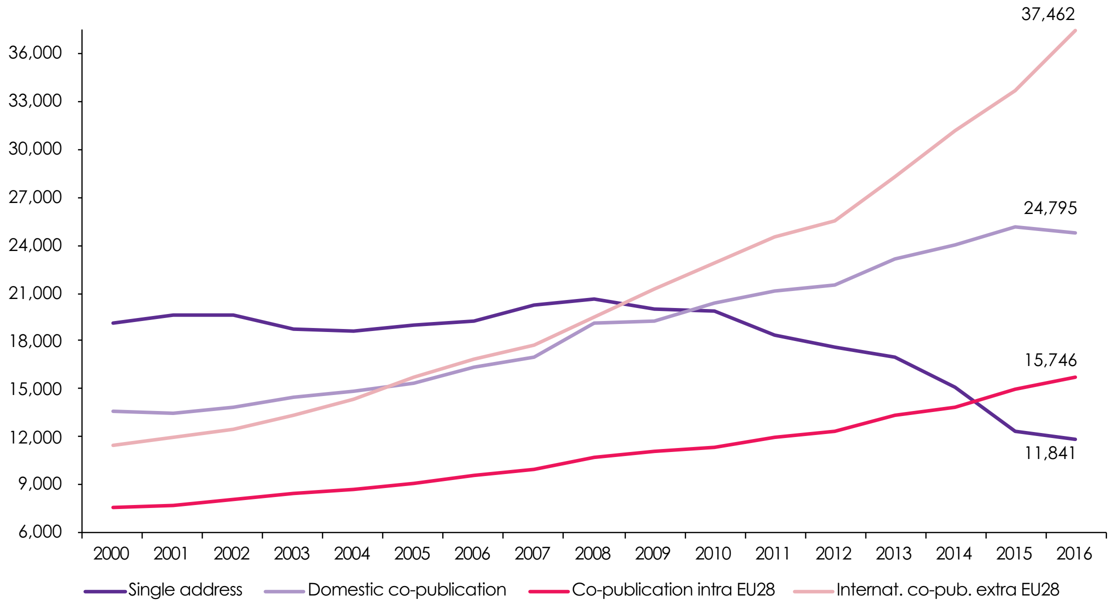
Source: Computed by OST using WoS

4.5. French international co-publications and their scientific impact

France has followed the global trend towards more co-publications, both between domestic institutions and with foreign institutions. Figure 37 thus presents a similar curve to that seen in Figure 5 (Section 2). Publications originating from a single institution first stagnated in pure numerical terms, before dropping off from the late-2000s onwards, putting France slightly ahead of the global curve (2013, Figure 5). In the meantime, co-publications between French institutions and international co-publications have both increased. Co-publications between French institutions and with partners from within the EU have followed a similar trajectory, growing less rapidly than international co-publications with non-EU partners. All in all, co-publications with foreign institutions, European or non-European, account for 58% of France's total publications.

Figure 37. Number of France publications by type of collaboration



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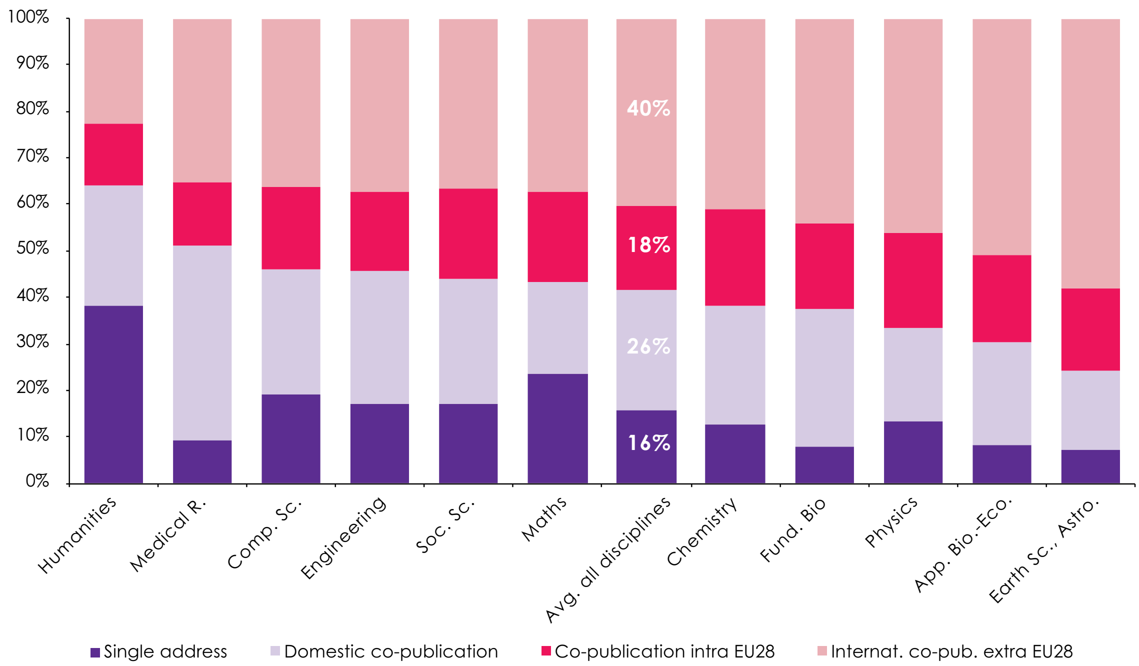
Source: Computed by OST using WoS

The rate of international co-publications varies considerably from one discipline to the next. The humanities have by far the highest rate of publications originating from a single French institution, and the lowest rate of international co-publications. Medical research is the second-least internationalised discipline (49%), due to the large proportion of co-publications involving multiple French institutions (Figure 38).

Figure 38. Distribution of France publications by type of collaboration, by discipline, 2016



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Source: Computed by OST using WoS

Mathematics, social sciences, computer science and engineering have an internationalisation rate close to the national mean. The two most internationalised disciplines are applied biology-ecology (70%) and earth sciences-astronomy-astrophysics (76%), with also the highest rate of co-publications with non-European institutions.

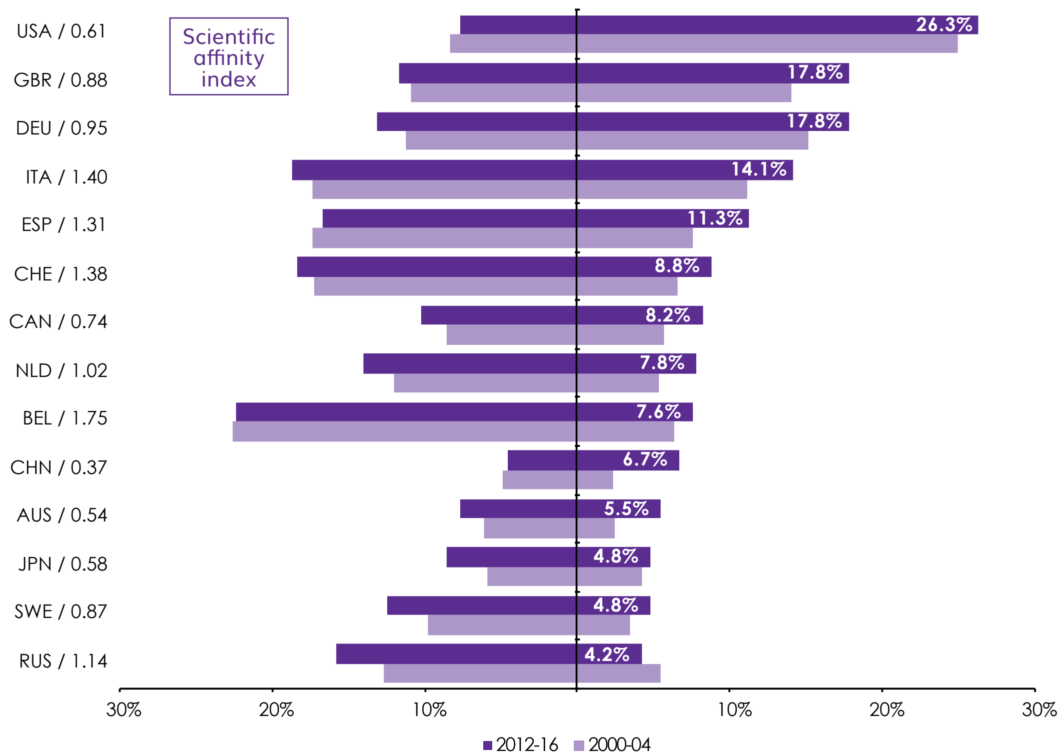
4.5.1. French international co-publications by partner country

Figure 39 breaks down France's international co-publications by partner, with three indicators for each country: the share of the country in total French co-publications and, conversely, the share of France in that country's international co-publications, along with an indicator measuring the scientific affinity between France and the partner in question. The affinity index compares the share of the country in France's international co-publications with the share of the country in total international co-publications. This indicator is symmetrical: the value will be same for the partner, as the number of French international co-publications will be switched with the number of co-publications by the partner in the formula. The affinity index is 1 if the partner co-publishes with France at its potential level, estimated as its share of total international co-publications.

The USA is France's leading scientific partner, but the scientific affinity between the two countries is moderate (0.6). Russia, on the other hand, is not a major research partner for France, and yet the affinity index is above the neutral value (1.1). Four of France's main scientific partners have affinity scores above 1: Belgium, with the highest affinity index (1.8), Italy (1.4), Switzerland (1.4) and Spain (1.3). However, the affinity indices for two other major European partners, Germany and the United Kingdom, fall short of the neutral value. These cooperation profiles demonstrate that, within the EU and beyond, European programmes to promote collaborative research, cultural and scientific affinities as well as geographical proximity are all significant factors when it comes to choosing research partners.

Among France's primary partners, China has the weakest scientific affinity index at barely 0.4. China's share in France's co-publications has increased substantially over the past decade, but at 7% it still remains low. Moreover, France's share of Chinese international co-publications has edged down over the same period. France's share in the international co-publications of the United States and Spain has also dropped, while increasing with other European partners as well as Australia and Japan.

Figure 39. Share of international co-publications of France with its main partners (right), share of France in their international co-publications (left), and scientific affinity index



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Source: Computed by OST using WoS

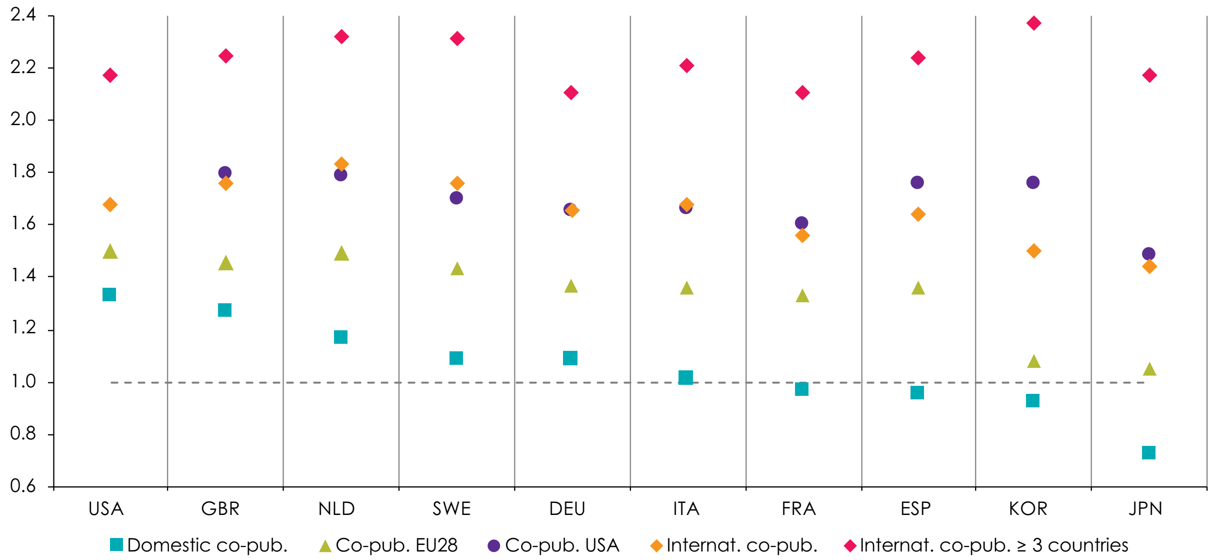
4.5.2. Impact of French co-publications, by partner country and by discipline

International co-publications tend to have above-average scientific impact, both at national (Winkler et al. 2015, Jonkers and Wagner 2017, OECD 2017) and institutional level (Khor and Yu 2016). This phenomenon is regularly observed, and may be partly due to the simple fact of having multiple authors, but also to the fact that, since international cooperation is a costly endeavour, projects and authors are subjected to a selection process. Alternatively, it might be the case that cooperation facilitates the emergence of particularly pertinent forms of synergy.

Figure 40a compares the impact of co-publications within the France benchmark group with the impact of other types of international co-publications. It shows that international co-publications have a greater impact than domestic co-publications[38], but the scale of the difference depends on the partners involved.

Co-publications between partners in the EU are frequent[39], but have an average impact inferior to that of co-publications with non-European partners. EU co-publications, which often involve multiple partners, are less impactful than bilateral co-publications with partners in the United States (Figure 40a). The impact of the latter is above the average for Spain's international co-publications. The impact of bilateral co-publications with partners in the United States is on a par with the average impact of international co-publications for several European nations, including France (1.6). For all countries in the benchmark group, the most impactful category is multilateral co-publications involving more than three countries. This impact is around 2.2 for most countries, and 2.3 for the Netherlands.

Figure 40a. Impact of co-publications by type of partners, France benchmark group, 2014



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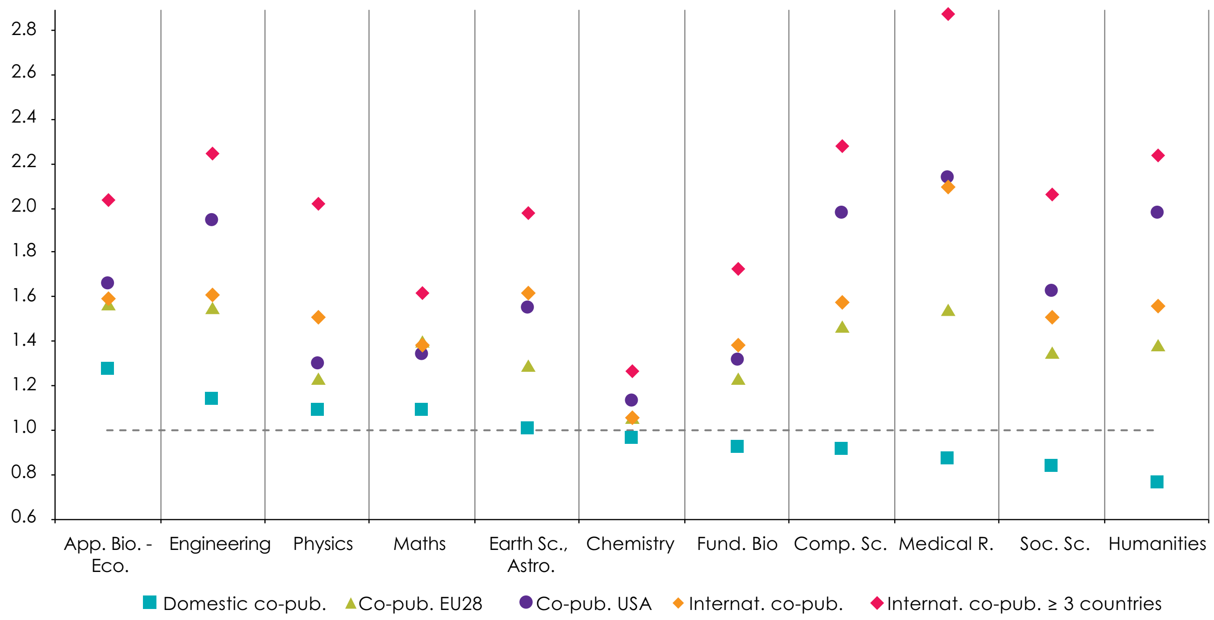
Source: Computed by OST using WoS

38. The latter generally have a greater impact than domestic publications involving no collaboration, not included in this graph.
39. Figure 39 offers an illustration in the case of France.

Figure 40b. Impact of French co-publications by type of collaboration and discipline, 2014



www.hceres.fr/OSTReport2019-Fig-40b

Source: Computed by OST using WoS

Figure 40b shows that the impact of France's international co-publications varies considerably from one discipline to the next. In mathematics, the impact of international co-publications is only slightly greater than that of domestic co-publications. The difference is much larger in medical research, computer science and the humanities. The disciplines for which the difference is most pronounced are medical research, social sciences and humanities. These disciplines generally have the smallest proportion of international co-publications (Figure 38).

The impact of co-publications with the United States tends to be greater than that of intra-EU co-publications, except in mathematics[40]. Their impact is above the average for all international co-publications in computer science, engineering, social sciences and humanities.

40. Glänzel (2001) calculates impact indicators for bilateral co-publications between a selection of countries. He demonstrates that the value of these impact indicators depends on the pairing of partner and discipline, although collaborating with certain countries always tends to have a positive influence on impact.

Conclusions

Global trends in scientific publications since 2000

Since the turn of the millennium, global output of scientific publications has been multiplied by 2.3. This report confirms the dynamic growth of world scientific output, as well as the contrasting growth rates of different geographical zones and countries. China, along with several other emerging nations, has seen its output grow much more rapidly than the world average; meanwhile, research-intensive countries have grown more slowly and seen their share of world publications slip back. The fall in the United States share of world output has been sharp, while the decline of the EU's share has been attenuated by the increased investment in research by certain member states.

In 2016, the EU produced nearly 28% of world scientific publications, ahead of the United States and China, which now have a similar volume of scientific publications. The ranking is however different in terms of scientific impact, the US being the leader, ahead of the EU and China. The US is also the leader in the top 1% most-cited publications. American universities produce a higher share of future Nobel laureates (Ph. Ds.) than European universities, while China only had one laureate between 1997 and 2017. Additionally, the US proves to be more attractive than the EU when these prize winners move from one institution to another during their career.

China's increasing share of world scientific publications has impacted their distribution by discipline since 2000. Medical research remains the discipline with the most publications, but fundamental biology was overtaken by chemistry in 2005 and by engineering in 2012. In 2016 chemistry was the second most-published discipline, with engineering in third. The number of engineering publications surpassed that of physics in 2009. In 2000, social sciences and humanities produced an equivalent volume of publications, but the progress of the social sciences has been noticeably greater. In 2000, computer science was the smallest discipline in terms of number of publications; by 2015 it had overtaken the humanities and mathematics.

Mathematics may be used as an illustration of the relative positions of the United States and China. China became the first publishing country in mathematics ahead of the United States in 2012. In the top 1% most highly-cited publications however, the United States is clearly ahead of China, their world shares being respectively 29% and 14%. Besides, the two countries are specialised in different research fields in mathematics, China in Applied Mathematics and the United States in Statistics & Probability.

This report has confirmed the increasing rate of international co-publications. Many countries have seen their rate of international co-publications increase, even if it remains relatively low in large countries. The report has also confirmed the positive influence of international co-publication on impact, but has clearly shown that the intensity of this positive influence depends on the partners. For example, intra-EU co-publications tend to have a lower impact than transatlantic co-publications across disciplines.

The position of France in world scientific publications

In this global scientific context, France's position has evolved more as a result of the dynamic of certain other countries than as a consequence of internal dynamics. France's annual number of scientific publications increased by 40% between 2000 and 2016, but over the same period France slipped from 5th to 8th place in terms of scientific contribution to world output. It was overtaken by China in 2006, by India in 2014 and by Italy in 2016. The volume of publications from South Korea continues to grow steadily, and its world share is now on a par with France. Within Europe, neighbouring countries have undergone more substantial quantitative or qualitative changes than France. Italy now produces a similar number of publications to France, with an equivalent average scientific impact. France retains a higher share of its publications in the top 1% most-cited than Italy, but the tables are turned when it comes to the top 10%. More broadly, a number of indicators show that the impact of France's scientific publications has increased since the start of the century, but this has not changed its relative performance compared with other major producers of academic publications. The average impact of French publications is 10% above the world average, while American publications are 30% above and Chinese publications 15% below that same global mean.

The disciplinary profile of French publications has changed relatively little, but some of the changes observed can be attributed to the consequences of China's exponential growth on the distribution of global academic output by discipline. China is strongly specialised in chemistry, and its growing share of world output has increased the relative weight of chemistry in world publications. This has also had the effect of driving down France's specialisation index in chemistry. By the same token, the clear increase observed in the French specialisation index for social sciences must be seen in the context of the very low share which this discipline occupies in Chinese output, thus reducing its share of total world output. France's increased specialisation in computer science also needs to be interpreted in light of the global context. This report underscores the differences in France's position within the disciplines of social sciences and humanities. Its specialisation and impact vary strongly from field to field within these general disciplines. This exploration suggests that it would be necessary to use a more detailed classification to analyse the dynamics of France's specialisation in these disciplines.

France remains strongly specialised in mathematics, with two major *foci*, on Fundamental Mathematics and Statistics & Probability. However, the impact of French publications in mathematics owes much to the field of Fundamental Mathematics.

With an international co-publication rate of 58%, France is close to the average for research-intensive countries of similar size, such as Germany. France's principal publishing partners are the USA and Europe's leading scientific nations. Nevertheless, co-publications with these countries are still not reaching their full potential, as measured by their share in total international co-publications. France has strong scientific affinity with Belgium, Italy and Spain, but low affinity with China. In this respect, France does not seem to have made the most of the boom in China's scientific capacities. The same could be said of the European Union as a whole, with less effort devoted to developing different channels of scientific and technological collaboration with China than the USA (Veugelers 2017). Within the EU, France collaborates much less with China than the United Kingdom in particular (OST 2019). In France as in other countries, the scientific impact of international co-publications is higher than the impact of domestic co-publications, but varies widely depending on the discipline and the partner country.

References

Abramo, G., Cicero, T., & D'Angelo, C. A. (2011). Assessing the varying level of impact measurement accuracy as a function of the citation window length, *Journal of Informetrics*, 5(4), 659-667

Adler, R., J., Ewing et P. Taylor, 2009, Citation statistics: A report from the international mathematical union (IMU) in cooperation with the international council of industrial and applied mathematics (ICIAM) and the Institute of Mathematical Statistics (IMS), *Statistical Science*, 24, 1–14. http://dx.doi.org/10.1214/09-STS285

▪ Albarran P., R. Carrasco et J. Ruiz-Castillo, 2014, « The Elite in Economics », Working paper Economic Series, 14-14, Universidad Carlos III de Madrid

ARWU, 2018, Academic Ranking of World Universities 2017, http://www.shanghairanking.com/ARWU2017.html

Banque mondiale, 2017, *Les données ouvertes de la Banque mondiale*, https://donnees.banquemondiale.org/

BEIS, 2017, International comparative performance of the UK research base 2016, Department for Business, Energy & Industrial Strategy https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/660855/uk-research-base-international-comparison-2016.pdf

Bornmann, L. et R. Haunschild, 2017, Does evaluative scientometrics lose its main focus on scientific quality by the new orientation towards societal impact?, *Scientometrics*, 110:937–943

▪ Campbell, D., C. Lefebvre, M. Picard-Aitken, G. Coté, A. Ventimiglia, G. Roberge et E. Archambault, 2013, *Country and regional scientific production profiles*, Publication Office of the European Commission

Castelvecchi, D., 2015, Physics paper sets record with more than 5 000 authors, *Nature*, doi:10.1038/nature.2015.17567

▪ Chinchilla-Rodriguez, Z., K. Ocana-Rosa et B. Vargas-Quesada, 2016, How to combine research guarantor and collaboration patterns to measure scientific performance of countries in scientific fields: Nanoscience and nanotechnology as a Case study, *Frontiers in Research Metrics and Analytics*, 1:2, doi: 10.3389/frma.2016.00002

Cohen, W. M. and D. A. Levinthal, 1990, '*Absorptive capacity: a new perspective on learning and innovation*', Administrative Science Quarterly

Cornell University, INSEAD, and WIPO, 2018: The Global Innovation Index 2018: Energizing the World with Innovation. https://www.wipo.int/edocs/pubdocs/en/wipo_pub_gii_2018.pdf

CWTS, 2018. CWTS Leiden Ranking 2017, http://www.leidenranking.com/ranking/2017/list

De Solla Price, D. J., 1976, A general theory of bibliometric and other cumulative advantage processes, *Journal of the American Society of Informetric Science*, 27, 292–306

▪ DGRI-DGE 2016, *L'innovation en France : indicateurs de positionnement international* https://www.entreprises.gouv.fr/files/files/directions_services/politique-et-enjeux/innovation/innovation-en-france-indicateurs-de-positionnement-international.pdf

▪ Dubois, P., J-C. Rochet et J-M. Schlenker, 2013, Productivity and mobility in academic research: evidence from mathematicians, *Scientometrics*, 98: 1669-1701

▪ Ellegaard, O. and J.A. Wallin, 2015, The bibliometric analysis of scholarly production: How great is the impact?, *Scientometrics*, 105: 1809–1831

▪ EU 2017, European Innovation Scoreboard 2017, European Commission

▪ EU 2018, European Innovation Scoreboard 2018, European Commission

Garousi, V. and J. M. Fernandes, 2017, Quantity versus impact of software engineering papers: a quantitative study, *Scientometrics*, 112:963–1006

Glänzel, W., 2001, National characteristics in international scientific co-authorship relations, *Scientometrics*, 51: 69–115

Glänzel, W., Thijs, B., and Schlemmer, B. (2004). A bibliometric approach to the role of author self-citations in scientific communication. *Scientometrics*, 59(1), 63-77

Helmich P.; Gruber S.; Frietsch R., 2018, Performance and Structures of the German Science System 2017. Studien zum deutschen Innovationssystem. Nr. 5-2018. Berlin: EFI

▪ : data on France, either overall or for certain disciplines/themes.

Khor, K. A. et L.-G. Yu, 2016, Influence of international co-authorship on the research citation impact of young universities, *Scientometrics*, 107: 1095-1110

Jones, B.F., S. Wuchy and B. Uzzi, 2008, Multi-university research teams: Shifting impact, geography and stratification in science, *Science*, 332

- Jonkers, K. and C. Wagner, Open countries have strong science, *Nature* 550, doi: 10.1038/550032a
- Mescheba, W. and Sachwald, F, 2018, Measures of the performance of France in Mathematics, STI 2018 Conference Proceedings, 12, https://hdl.handle.net/1887/64521

Monaco, S., M. Wikgren, S. Gerdes Barriere, J. Gurell, S. Karlsson and H. Aldberg, *The Swedish Research Barometer 2016*, Swedish Research Council

Narin, F. and E. Whitlow, 1990, *Measurement of scientific cooperation and co-authorship in CEC-related areas of science*, Office for Official Publications of the European Communities

- NSF, 2016, National Science Board, *Science and Engineering indicators 2016*

NSF, 2018, National Science Board, *Science and Engineering indicators 2018*

OECD, 2015, Frascati Manual 2015, Guidelines for Collecting and Reporting Data on Research and Experimental Development

OECD, 2016, *Compendium of Bibliometric Science Indicators*, http://oe.cd/scientometrics

- OECD 2017, *OECD Science, Technology and Industry Scoreboard*
- OST, 2019, Euro-China Science and Technology Collaboration in a Global Context, Science and Technology Observatory - Hcéres

Panaretos, J. and C. Malesios, 2012, *Influential Mathematicians: Birth, Education and Affiliation*, MPRA Paper No. 68046, https://mpra.ub.uni-muenchen.de/68046/

Pritychenko, B., 2016, Fractional authorship in nuclear physics, *Scientometrics*, 106:461–468

Rodriguez-Navarro, A., 2016, Research Assessment Based on Infrequent Achievements: A Comparison of the United-States and Europe in terms of Highly Cited papers and Nobel Prizes, *Journal of the Association for Information Science and Technology*, 67(3): 731-40

- Schlagberger, E.M., L. Bornmann and J. Bauer, 2016, At what institutions did Nobel laureates do their prize- winning work? An analysis of biographical information on Nobel laureates from 1994 to 2014, *Scientometrics*, 109:723–767

SEFRI, 2018, *Les publications scientifiques en Suisse, 2006-2015*, Rapport du Secrétariat d'État à la formation, à la recherche et à l'innovation

Stephan, P., 2012, *How Economics Shapes Science*, Harvard University Press

Sugimoto, C. R. and V. Larivière, 2018, *Measuring research. What everybody needs to know,* Oxford University Press

Sugimoto, C. R., N. Robinson-Garcia, D. S. Murray, A. Yegros-Yegros, R. Costas and V. Larivière, 2017, Scientists have most impact when they're free to move, *Nature* 550, doi: 1038/550029a

- Turner et al. 2016, Publishing and perishing — bibliometric output profiles of individual authors worldwide, in: *Science, Research and Innovation performance of the EU*, pp. 162-167.

UNESCO, 2015, *Rapport de l'UNESCO sur la science*, Éditions UNESCO

UNESCO, 2017, Statistiques de l'UNESCO, section Science, Technologie et Innovation, http://data.uis.unesco.org/?lang=fr

Veugelers, R., 2017, The challenge of China's rise as a science and technology powerhouse, *Policy Contribution*, Issue n°19, Bruegel

Waltman, L., 2016, A review of the literature on citation impact indicators. *Journal of Informetrics*, 10(2), 365–391

Wang, L., 2016, The structure and comparative advantages of China's scientific research: quantitative and qualitative perspectives, *Scientometrics*, 106:435–452, DOI 10.1007/s11192-015-1650-2

Wilsdon, J. et al., 2015, *The Metric Tide: Report of the Independent Review of the Role of Metrics in Research Assessment and Management*, DOI: 10.13140/RG.2.1.4929.1363

Winkler, A. E., W. Glänzel, S. Levin et P. Stephan, 2015, The diffusion of the Internet and the increased propensity of teams to transcend institutional and national borders, *Revue Économique*, janvier

Zhou, P. et H. Tian, 2014, Funded collaboration research in mathematics in China, *Scientometrics*, 99:695–715

Zhou, P. et X. Lv, 2015, Academic publishing and collaboration between China and Germany in physics, *Scientometrics*, 105: 1875-87

Annexes

A1. Methodology

This methodological annex provides more details of the bibliometric analyses contained in this report. For other types of data (the first section, and the analysis of the movements of Nobel Prize laureates), the sources and methods used are all explained in the body of the text.

1. Database and disciplinary classification

The bibliometric analyses are based on the OST database, which is an in-house version of Web of Science acquired from Clarivate Analytics. The Web of Science is one of the main databases used in bibliometrics:* it indexes the most influential international scientific journals and conference proceedings. It focuses on academic publications, particularly on scientific periodicals. It is more representative for internationalised disciplines than it is for applied disciplines, or disciplines with strong national traditions. It is less representative for certain fields of medical research, engineering, social sciences and humanities. Nevertheless, the coverage of this database continues to evolve and new journals are added every year, using the selection process established by Clarivate Analytics[1].

The division of the OST bibliometric database into 11 major disciplines is derived from the aggregation of the journal-based subject categories[2] defined by Clarivate Analytics. The 11 major disciplines are:

- Applied biology-ecology,
- Fundamental biology,
- Chemistry,
- Computer science,
- Mathematics,
- Physics,
- Medical research,
- Earth sciences-Astronomy-Astrophysics,
- Humanities,
- Engineering,
- Social sciences.

Journals may be assigned to multiple subject categories or research fields and thus, *via* the aggregation process, to multiple disciplines. Articles published in multidisciplinary journals (*Nature*, *PNAS* and *Science*, for example) are assigned to one of the major disciplines based on their subject matter.

While the WoS contains several types of documents, only certain documents are retained to produce the indicators: original articles (including those collected in proceedings), reviews and letters.

In the second section these indicators are calculated for the major disciplines, and some are calculated at a finer grain for social sciences and humanities. In the section dedicated to mathematics, most of the indicators are also calculated for the four research fields which make up the discipline (Fundamental Mathematics, Applied Mathematics, Statistics & Probability, Mathematics for interdisciplinary applications).

1. More detailed information is available on the website: https://clarivate.com/products/web-of-science/
2. For a complete list, see: https://images.webofknowledge.com/WOK48B3/help/WOS/hp_subject_category_terms_tasca.html

2. Counting methods

Scientific publications are often signed by two or more authors. They may also be co-authored by different institutions or different countries. There are two main methods used to count these publications: whole and fractional counting.

Whole counting

Whole counting involves assigning full credit to each signatory of a given publication. Similarly, if the publication is indexed in two research fields, it will be counted as 1 publication in each field. To the extent that each publication is counted as many times as there are signatories, whole counting is not additive.

Fractional counting

The aim of fractional counting is to measure the contribution of signatories of scientific publications. A fraction of the publication, equivalent to her contribution, is attributed to each signatory. It allows adding up the fractions without counting the publication more than once. Fractional counting is additive on all scales and at all levels of classification, allowing to calculate shares in the total. It is therefore better suited to comparative analyses between institutions and countries, for example.

The use of fractional counting can be illustrated by taking the example of a publication co-signed by two authors affiliated with two institutions, one in France and the other in Germany. This publication may also be assigned to three different research fields and two disciplines in the database, for example 'Statistics & Probability' and 'Applied Mathematics' within the mathematics and 'Artificial intelligence' within the Computer science. In this example, fractional counting of the publication is applied to both the geographical and disciplinary dimensions. Each country will be credited with one half (1/2) of the publication. From a disciplinary perspective, the publication will be counted as 2/3 mathematics and 1/3 computer science. Total fractionalization combines the two fractions established above in order to represent country/field or country/discipline combinations. The share assigned to a country/discipline pairing is the sum of the corresponding geographical and disciplinary fractions. In this example, 1/6 of the publication credit is awarded to each country/computer science pairing, and 2/6 for each country/mathematics pairing. As such, France and Germany both receive 1/6 + 2/6 = 1/2.

In this report both types of counting are used. Whole counting is used as the most appropriate method for calculating indices relating to scientific collaboration, since the aim is to count the number of collaborations. Fractional counting is used for output, specialisation and impact indicators, where the aim is to establish comparisons between countries and/or disciplines.

3. Indicators for scientific publications

This report contains three major families of indicators: indicators for output, impact and collaboration. All of these indicators are calculated based on papers published during 2000-2016 (2014 for impact). Changes over the period 2000 - 2016 are given year by year, or else by comparing different periods. The report generally compares two 5-year periods: 2000-2004 and 2012-2016. The section dealing with mathematics compares two 3-year periods, 2000-02 and 2011-13, in order to allow for a longer citation window (see Table A1).

Share of publications

The share of publications in a given research area is defined by the number of scientific papers associated with a country in this discipline or research field divided by the world's publications number in the same discipline or field.

Specialisation

The scientific specialisation index of a country is defined by the share of the discipline in the country's publications, divided by the share of the same discipline in the publications worldwide.

It is equal to 1 if the country's share in the discipline equals the country's share in all fields indicating no specialisation. The higher the specialisation index is above 1, the more specialised the country is in that discipline.

Impact indicators

Impact indicators are based on references made in scientific publications to earlier papers.

Number of citations and citation window

The total number of citations summed over N years is defined as the number of citations received in N years by all of a country's publications. The value of N defines the citation window, and includes the year of publication. For Sections 1 to 3, we use a 3-year citation window. The choice of a 3-year window is based on various bibliometric studies which show that, for analysis at an aggregated level, a 3-year window is sufficient to calculate the bibliometric indicators (Glänzel et al. (2004); Abramo et al. (2011), Waltman (2016)).

For more fine-grained analysis, the choice of citation window must take into account the specificities of different fields of research. For example, a 3-year citation window is not long enough in mathematics (Abramo et al. 2011). Correlating the rankings of all countries publishing in this discipline shows that from 4 years onwards the rankings are very stable.

Table A1 shows the ranks correlation degree of countries when they are ordered by number of citations received by their publications in Mathematics. Citation windows from 3 to 10 years are noted F3, F4, ... , F10. F11+ means no window: all of the citations received by a publication are counted, with no time limit. Each intersection of line and column gives the Spearman correlation coefficient between the respective citation windows. The table shows that the country ranks stabilise (the correlation coefficient is above 0.9) with a citation window of 4 years and upwards.

The same analysis was repeated for each field. Examining the rankings for each field in the discipline shows that, for a correlation threshold of 0.9, the country rankings are less stable with a 4-year window. This is particularly true of Fundamental Mathematics and Applied Mathematics. We therefore opted to use a 5-year citation window when calculating the impact indicators in the section of the report dedicated to the discipline of mathematics. In doing so our aim was to ensure the stability of the country rankings for the discipline as a whole and for the different fields of research in mathematics.

Table A1. Correlation of country rankings based on the number of citations received in mathematics, by citation window

	3-year	4-year	5-year	6-year	7-year	8-year	9-year	10-year	11+year
3-year	1.00								
4-year	0.95	1.00							
5-year	0.93	0.99	1.00						
6-year	0.92	0.97	0.99	1.00					
7-year	0.90	0.95	0.96	0.97	1.00				
8-year	0.90	0.95	0.96	0.97	1.00	1.00			
9-year	0.90	0.95	0.96	0.97	1.00	1.00	1.00		
10-year	0.88	0.93	0.95	0.96	0.99	0.99	0.99	1.00	
11+year	0.88	0.91	0.92	0.93	0.96	0.96	0.96	0.95	1.00

Field-normalised impact (FNI)

Publication and citation practices differ between disciplines. Alder et al. (2009) have shown that mathematics is the discipline in which publications tend to attract the fewest citations. The number of citations per publication is therefore not statistically comparable between disciplines without certain methodological precautions.

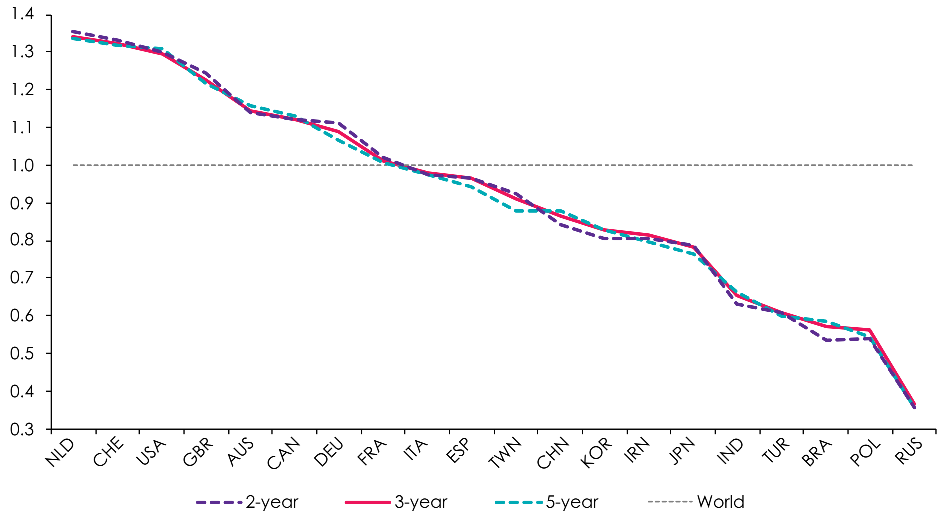
The field-normalised impact of a country's research is defined as the average number of citations received by the country's publications, normalised by the average number of citations received by world publications in the same field and the same year.

The value of the indicator for a given discipline is a weighted average of the values for each of its constituent fields of research.

By construction, the world FNI is equal to 1. If a country has an FNI score above (or below) 1, its publications are more (or less) cited than the world average.

Figure A1. gives the FNI indicators for publications in 2010 at windows of 2, 3 and 5 years.

Figure A1. FNI indicators for publications with different citation windows, across all disciplines, by country



www.hceres.fr/OSTReport2019-Fig-A1

Source: Computed by OST using WoS

Journal Normalised Impact (JNI)

The journal-normalised impact indicator for a given domain measures the impact a country's publications would have if each was to receive the average number of citations (ANC) received by articles published in the journal in question. JNI is defined as the country's mean ANC, normalised by the world average for citations per paper in this field.

The value of the indicator for a given discipline is obtained by calculating a weighted average of the JNI scores for each of the fields in the discipline.

By construction, JNI is 1 for the world. If a country has a JNI score higher (or lower) than 1, its publications appear in journals which are more (or less) highly-cited than the world average.

As with the indicator for the impact of publications, JNI is calculated using a citation window which may vary.

Percentile-based indicators and activity index

Percentiles are a method for normalizing the citation scores received by scientific publications. For a given research field, publication year and citation window, all publications are sorted by citation numbers and grouped in percentiles. Each publication is then positioned within the citation distribution of its field. According this classification, the top x% of the most highly-cited publications in the world thus corresponds to the x% of world publications receiving the most citations.

In theory, the share of publications ranked in the x most-cited percentiles should be exactly equal to x% of the world's total publications. In practice this is not quite true, because many publications receive the same number of citations (including zero). Hence the importance of calculating activity indexes, which provide a simple frame of reference for international comparisons. The activity index for a country, defined by class (percentile or percentiles regrouped), is the ratio between the share of this country's publications in the class and the share of world publications falling into this same class. An activity indicator greater than (or less than) 1 means that the country's presence in this category is above (or below) the world average.

Co-publication indicators

Different types of co-publication (national, international etc.) are identified on an institutional basis. A work is considered to be a co-publication if it is affiliated with two different addresses, even if it is published by a single author. Similarly, a publication with multiple authors will be considered an individual publication if all of the signatories are affiliated with the same institutional address.

Number and share of co-publications

A national co-publication is a publication for which all the addresses of authors' affiliations are within the same country. When a partnered publication involves one or more institutions from another country, we use the term international co-publication. A co-publication involving authors from institutions located in just two countries is known as a bilateral international co-publication.

For a given country, the term "share of co-publications" refers to the number of co-publications as a proportion of the country's total publications.

For a given country, "share of international co-publications" measures the number of international co-publications as a proportion of the country's total publications. Propensity to collaborate, particularly with overseas institutions, varies between different fields of research. In order to make comparisons between fields and disciplines, we thus need to normalise the co-publication rates.

A country's internationalisation indicator for a given discipline measures its rate of international co-publication compared with the rate of international co-publications by all countries within that discipline. If the indicator is greater than 1, the country has an above-average tendency to collaborate with overseas partners in this discipline.

Scientific affinity index

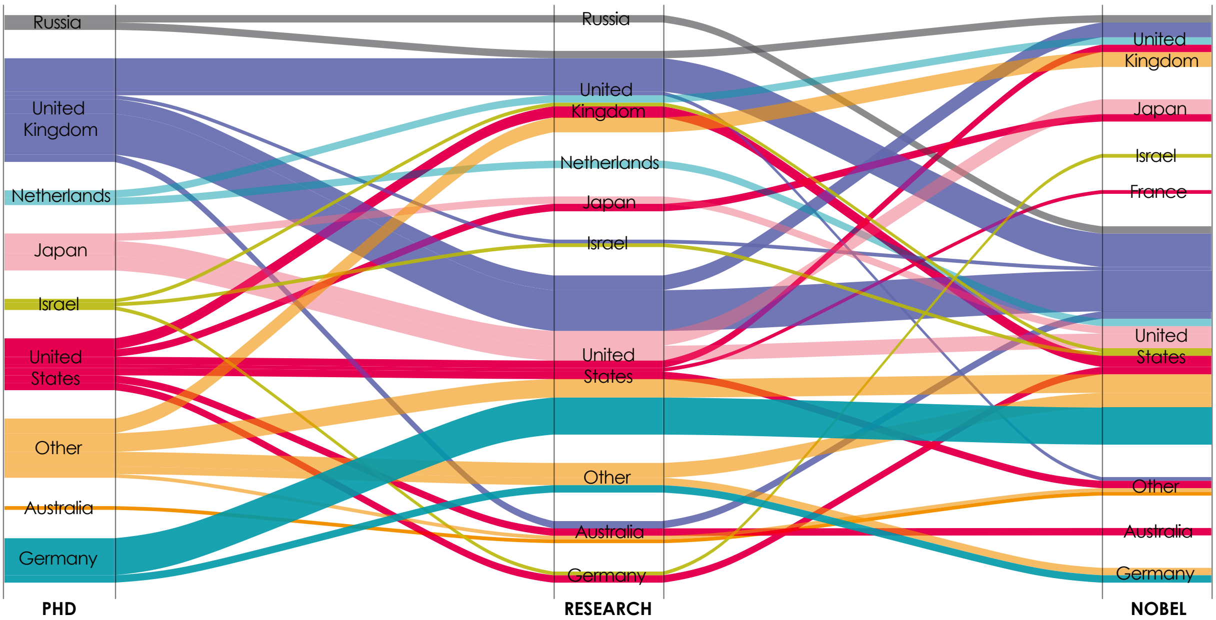
The scientific affinity index is calculated for pairs of countries. It measures the intensity of scientific collaboration between two countries, set against their potential for international collaboration. For two countries A and B, the affinity index involves two ratios: the share of A's co-publications with B in A's total international co-publications, the share of B's international co-publications in the global total of international co-publications. The indicator is symmetrical between A and B.

A2. Mobility of Nobel laureates

The figure below is a complement to Figure 12 and Table 4 featured in the body of the report. It focuses on those laureates who have moved internationally at least once in their career after obtaining their doctorate, either for the decisive research work which earned them the Nobel Prize ('Research'), or at the time the prize was awarded ('Nobel').

Since none of the French winners moved to overseas institutions, France is not listed among the countries where doctoral degrees were awarded. One of the laureates based in the United States during the Research phase had moved to France by the time the prize was awarded, hence France appears in the 'Nobel' column.

Figure A2. International mobility of the scientific Nobel laureates, 1994-2017, researchers moving for at least one of the key stages of their career



www.hceres.fr/OSTReport2019-Fig-A2

Source: Computed by OST based on data from Schalgberger et al. (2016) and the Nobel Prize website.

A3. Highly-cited publications: Top 10%

Table A3. Proportion of publications among the top 10% of world's most-cited, 2014

Country	PP Top 10%
GBR	14.8
NLD	14.3
DNK	13.2
BEL	12.6
IRL	11.9
SWE	11.5
DEU	11.5
AUT	11.5
LUX	11.4
FRA	11.3
EU28	11.1
FIN	10.7
ITA	10.1
CYP	9.6

Country	PP Top 10%
ESP	9.5
MLT	9.4
PRT	8.9
GRC	8.7
SVN	8.3
EST	7.8
CZE	6.7
HUN	5.7
SVK	5.3
POL	4.8
ROU	4.8
HRV	4.1
LTU	3.7
LVA	3.7
BGR	3.6

Source: European Innovation Scoreboard (EU 2016)

A4. Corpora in mathematics

Table A4a. List of journals rated A* by the *Australian Mathematical Society*

Rank	Journal Name	ISSN
A*	Acta Mathematica	0001-5962
A*	Acta Numerica	0962-4929
A*	Advances in Mathematics	0001-8708
A*	Advances in Theoretical and Mathematical Physics	1095-0761
A*	American Journal of Mathematics	0002-9327
A*	Annals of Mathematics	0003-486X
A*	Archive for Rational Mechanics and Analysis	0003-9527
A*	Calculus of Variations and Partial Differential Equations	0944-2669
A*	Chaos	1054-1500
A*	Commentarii Mathematici Helvetici	0010-2571
A*	Communications in Mathematical Physics	0010-3616
A*	Communications in Partial Differential Equations	0360-5302
A*	Communications on Pure and Applied Mathematics	0010-3640
A*	Duke Mathematical Journal	0012-7094
A*	Ergodic Theory and Dynamical Systems	0143-3857
A*	Geometric and Functional Analysis	1016-443X
A*	Geometry and Topology	1465-3060
A*	Indiana University Mathematics Journal	0022-2518
A*	Inventiones Mathematicae	0020-9910
A*	Inverse Problems	0266-5611
A*	Journal of Algebra	0021-8693
A*	Journal of Combinatorial Theory, Series A	0097-3165
A*	Journal of Combinatorial Theory. Series B	0095-8956
A*	Journal of Differential Equations	0022-0396
A*	Journal of Differential Geometry	0022-040X
A*	Journal of Functional Analysis	0022-1236
A*	Journal of Geometry and Physics	0393-0440
A*	Journal of Physics A: Mathematical and Theoretical	1751-8113
A*	Journal of the American Mathematical Society	0894-0347
A*	Mathematical Programming	0025-5610
A*	Mathematics of Operations Research	0364-765X
A*	Mathematische Annalen	0025-5831
A*	Nonlinearity	0951-7715
A*	Numerische Mathematik	0029-599X
A*	Physica D-Nonlinear Phenomena	0167-2789
A*	London Mathematical Society. Proceedings	0024-6115
A*	SIAM Journal on Applied Mathematics	0036-1399
A*	SIAM Journal on Control and Optimization	0363-0129
A*	SIAM Journal on Numerical Analysis	0036-1429
A*	SIAM Journal on Optimization	1052-6234
A*	SIAM Review	0036-1445
A*	Studies in Applied Mathematics	0022-2526
A*	Transactions of the American Mathematical Society	0002-9947
A*	Bulletin of the American Mathematical Society	0273-0979
A*	Annales Scientifiques de l'Ecole Normale Superieure	0012-9593
A*	Applied and Computational Harmonic Analysis	1063-5203
A*	Journal of the European Mathematical Society	1435-9855
A*	Institut des Hautes Etudes Scientifiques, Paris. Publications Mathematiques	0073-8301
A*	Journal fuer die Reine und Angewandte Mathematik: Crelle's journal	0075-4102
A*	Journal of Mathematical Logic	0219-0613
A*	Annals of Applied Probability	1050-5164
A*	Annals of Probability	0091-1798
A*	Annals of Statistics	0090-5364
A*	Journal of Business and Economic Statistics	0735-0015
A*	Journal of Computational and Graphical Statistics	1061-8600
A*	Journal of Statistical Mechanics: Theory and Experiment	1742-5468
A*	Journal of the American Statistical Association	0162-1459
A*	Journal of the Royal Statistical Society Series B: Statistical Methodology	1369-7412
A*	Probability Theory and Related Fields	0178-8051
A*	Statistics in Medicine	0277-6715
A*	Annals of Applied Statistics	1932-6157
A*	Biometrika	0006-3444
A*	Journal of Mathematical Biology	0303-6812
A*	Nuclear Physics, Section B	0550-3213
A*	Journal of Fluid Mechanics	0022-1120
A*	Physics of Fluids	1070-6631
A*	Journal of the Mechanics and Physics of Solids	0022-5096
A*	Operations Research	0030-364X
A*	Journal de Mathematiques Pures et Appliquees	0021-7824
A*	American Mathematical Society. Memoirs	0065-9266
A*	Annales de l'Institut Henri Poincaré (C) Analyse Non Linéaire	0294-1449
A*	Biometrics	0006-341X
A*	Journal of Computational Physics	0021-9991
A*	Journal of Theoretical Biology	0022-5193
A*	The Journal of High Energy Physics	1029-8479
A*	Biostatistics	1465-4644
A*	Journal of Physics A: Mathematical and General	0305-4470

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Source: https://www.austms.org.au/Rankings/AustMS_final_ranked.html

Table A4b. Number of publications[a] for each corpus, Mathematics benchmark group

Country	Number of publications in maths, WoS 2000-16	Number of publications in A* journals 2000-16	Number of publications in top 1% most-cited for maths 2000-13
Germany	33,654	5,536	205
Austria	4,880	723	38
Belgium	5,483	715	41
Canada	18,767	2,721	119
China	96,255	5,120	734
Spain	21,023	2,391	129
USA	122,999	26,175	1,435
France	40,059	7,895	306
Iran	10,484	174	105
Israel	7,879	1,381	42
Italy	26,289	3,549	156
Japan	24,730	3,076	93
Netherlands	6,033	826	35
Romania	6,748	302	52
UK	25,239	4,769	234
Russia	22,983	944	33
Sweden	4,889	710	31
World	**648,292**	**81,428**	**6,223**

a. Fractional counting, rounded to nearest whole unit.

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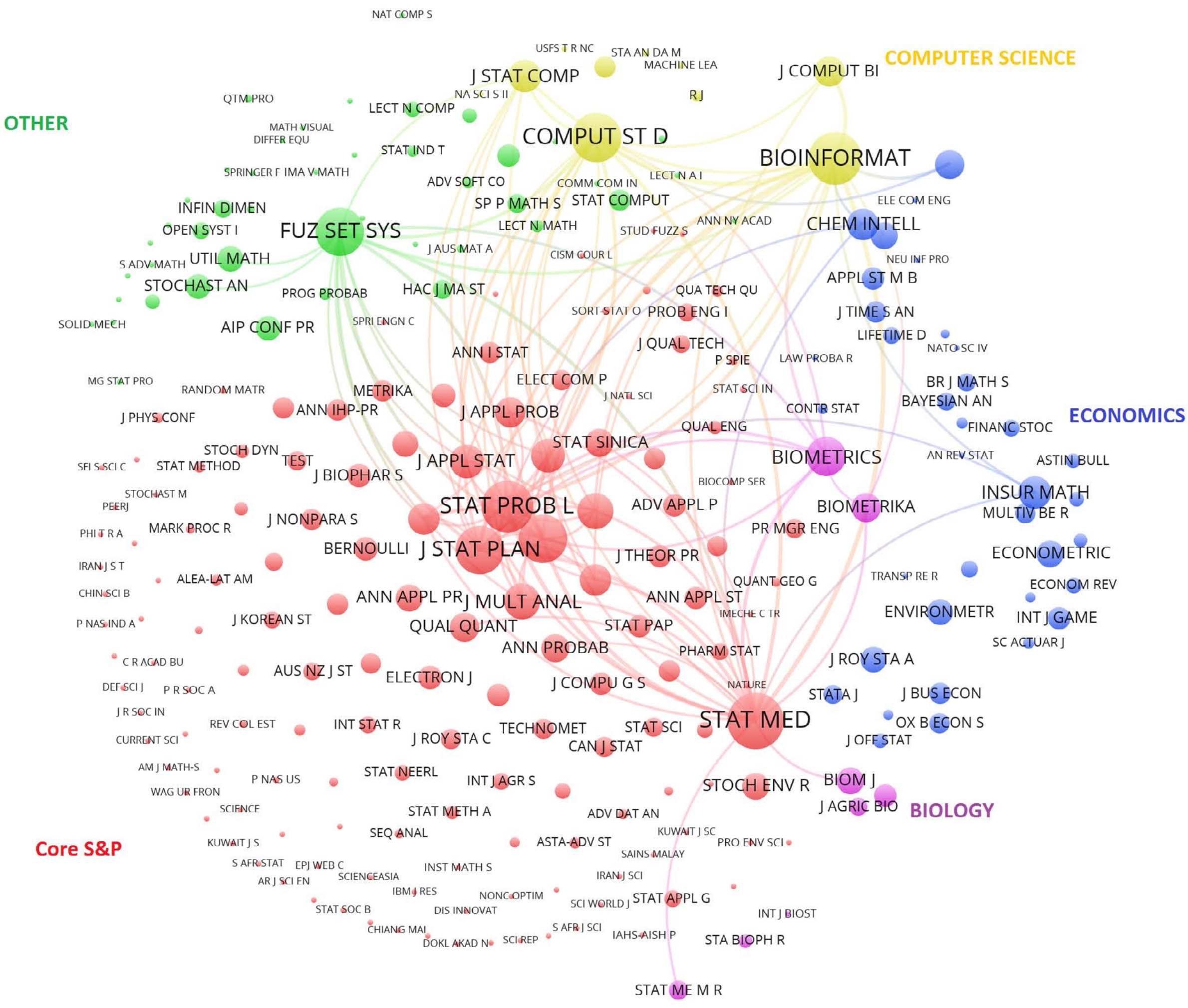
Source: Computed by OST using WoS

A5. Maps of Statistics & Probability journals

A profile has been created for each Stat. & Proba. journal, based on the subject categories assigned to each publication. The set of profiles is then used to create journal clusters whose links to Stat. & Proba. are defined by common subject categories (Mescheba and Sachwald 2018).

Figure A5 shows the global map of clusters. It contains 5 clusters for all Stat. & Proba. publications. The Core Stat. & Proba. cluster corresponds to journals that are focused on the Stat. & Proba. and do not deal with other subject or applied issues.

Figure A5: Stat. & Proba. publications by journal, World



Source: Computed by OST using WoS

Countries are compared on the basis of their share of publications in each cluster and of the corresponding impact indicators.

Publications from France are more often in Core of Stat. & Proba. journals. Table A5.a summarises the results of this clustering. It shows that the United Kingdom and the Netherlands have a relatively high proportion of Stat. & Proba. publications dealing with Economics/Finance/Insurance and the United States has the highest proportion of journals also classified in Biology. The United States and Belgium have the highest proportions of journals also classified in Computer science.

Table A5a. Clusters of Stat. & Proba. journals based on their proximity with other subject categories, 2000-16

Share of publications in cluster:	FRA	NLD	USA	BEL	GBR	World
Core Stat. & Proba.	70.8%	61.2%	60.6%	53.8%	52.5%	59.3%
Economics	10.4%	23.1%	14.2%	19.2%	23.7%	14.6%
Computer science	6.8%	8.4%	10.7%	11.5%	9.0%	9.7%
Biology	2.3%	3.9%	9.8%	7.0%	7.1%	5.7%
Other	9.8%	3.3%	4.7%	8.6%	7.7%	10.7%

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Source: Computed by OST using WoS

Table A5.b (World) confirms that publications in the Core Stat. & Proba. cluster tend to be less cited than those from the Economics, Biology and Computer science clusters. However, it shows that the impact of French publications in each of the clusters is not high compared to the benchmark countries. Their impact is the lowest for the Core Stat. & Proba. and the Biology clusters. It is the second highest behind the USA for the Economics cluster.

Table A5b. Citations by publication, normalized by the world total for Stat. & Proba.

Cluster	FRA	NLD	USA	BEL	GBR	World
Core Stat. & Proba.	0.96	0.98	1.17	1.04	1.15	0.90
Economics	1.39	1.31	1.52	1.27	1.26	1.22
Computer science	2.64	2.46	2.75	2.18	2.94	2.10
Biology	1.59	1.63	1.60	1.65	1.68	1.52
Other	0.68	0.69	0.65	1.09	0.79	0.70
All Stat. & Proba.	1.00	1.38	1.27	1.53	1.51	1.00

www.hceres.fr/OSTReport2019-Tab-A5b

Source: Computed by OST using WoS

A6. Glossary

Absorption / Absorptive capacity

The absorptive capacity of a company was originally defined as a firm's capacity to recognise the value of new information, assimilate it and apply it for commercial purposes. The concept was first theorised in an influential article published in 1990 (Cohen and Levinthal, 1990).

Affinity (scientific)

Scientific affinity is associated with co-publications between two countries. The scientific affinity indicator compares the rate of actual co-publication between two countries with their potential rate of co-publication, inferred from the relative weight of the two partners in total world co-publications.

Article (scientific)

A scientific article is a format for the dissemination of scientific information and research results generated by one or more researchers, aimed primarily at their peers and published in peer-reviewed journals. Generally, published articles are supplied with metadata which are essential for the purpose of identifying and comparing articles: journal in which it was published, title, names and affiliations of the authors, an abstract, keywords, references to other articles and a DOI handle.
See also *Publication*.

Benchmark group

France benchmark group

France, Germany, Italy, Japan, Netherlands, South Korea, Spain, Sweden, United Kingdom, United States.

Mathematics benchmark group

Austria, Belgium, Canada, China, France, Germany, Iran, Israel, Italy, Japan, Netherlands, Romania, Russia, Spain, Sweden, United Kingdom, United States.

Bibliographic / bibliometric database

A bibliographic database is a register of bibliographic items (scientific articles, books etc.). Thanks to widely-used cataloguing standards, databases of this type allow users to rapidly find specific documents, publications by specific authors, publications on similar topics (using key words), etc. A bibliometric database is necessarily a bibliographical database, but the opposite is not true. In addition to the standard information which any bibliographic database must contain, bibliometric databases also include information relating to the impact of a publication or journal in the scientific community, through citation indexing.

Bibliometrics / scientometrics

Bibliometrics is the practice of developing and applying quantitative indicators to measure scientific output, impact or collaboration by analysing publications and their bibliographic references. Scientometrics is broader, and may be defined as the science of measuring and analysing science. That means applying bibliometric techniques to the study of science and technology, while also analysing funding arrangements, human resources, patents, etc. In practice, there is considerable overlap between scientometrics, bibliometrics and other fields of analysis such as information science or the analysis of research and innovation systems.

Citation

A citation allows authors to refer readers to previous publications. Citations are considered as a measure of the academic influence or scientific impact (see below). An article which generates a large number of citations is thus assumed to be of particular importance within the scientific community.

Normalised citation

Normalisation consists in dividing the number of citations accumulated by a given publication by the average number of citations in the category to which it belongs. Normalisation allows us to make comparisons between different fields, as long as the citation practices which prevail in each field are taken into account.

Citation window

Represents the period of time, including the year of publication, for which the citations received by a publication are counted. Generally 2, 3 or 5 years. In this report we use a 3-year window, except for the section dedicated to mathematical research where a 5-year citation window is used.

Classification (disciplinary)

Disciplinary classification consists in grouping journals based on the citations links which connect them within their respective disciplines (see below). A single journal may cover multiple fields. Disciplines can be aggregated at different levels. Many classification systems exist. The Web of Science and Scopus for example have developed their classification systems.

Co-publication

A co-publication is a publication jointly signed by at least two different public and/or private institutions, based in the same country and/or different countries.

Bilateral co-publication

A bilateral co-publication is a publication with affiliations in just two countries.

International co-publication

To be considered an international co-publication, a publication must be affiliated with at least one address in its country of origin and one address elsewhere in the world.

Domestic co-publication

A co-publication is considered to be strictly national if it is not affiliated with any addresses outside the country in question.

Counting: whole/fractional

Whole counting involves assigning full credit to each signatory of a given publication (researchers, institutions, countries etc.). Fractional counting splits credit for a publication or citation between its contributors. The same principle is applied to citations. Credit may also be divided between disciplines (for multi-disciplinary publications). In this report, fractional counting indicates that the credit has been split at both levels (geographical and disciplinary). See the Methodology annex for further details.

Discipline

Disciplines are key units of analysis in studying and measuring research activities. A scientific discipline corresponds to a community of researchers working on the same or similar topics, participating in the same conferences and publishing in the same journals. From a technical perspective, the perimeter of a discipline is defined by the corresponding professional classification systems. For publications, the classifications used in databases vary: they may be more or less detailed, with more or less precise distinctions between different research disciplines and fields.

GDP

Gross domestic product is the principal indicator used to measure the economic output generated within a country during a given period (1 year generally). It accounts for the total value of the output of all resident agents within that country.

Impact (scientific, academic)

"For the past few decades, scholarly impact has been defined as an effect upon the scientific community, as measured through citations" (Cassidy and Larivière 2018). In bibliometrics, scholarly impact is often measured using indicators which focus on citations.

OECD

The Organisation for Economic Co-operation and Development (OECD) is an international organisation founded in 1961. It currently has 35 member nations.

Its role is to promote policies which increase economic and social well-being. It advises governments on various topics (trade, public finances, fighting corruption, promoting growth through innovation, environmental policy, education, etc.). The OECD produces or collates a wide array of statistics, and issues recommendations for statistical production.

PPP

Purchasing power parity (PPP) ratios are currency conversion rates which serve to level the purchasing power of different currencies by cancelling out differences in prices between countries.
GDP expressed in PPP is gross domestic product converted into international dollars using purchasing power parity ratios. An international dollar has the same purchasing power in the currency of the country in question as one American dollar in the United States.

Public expenditure on R&D (gross)

Gross public expenditure on R&D corresponds to all R&D spending by the government (including research bodies), higher education and non-profit institutions within the national perimeter. The scope of this expenditure is specified in the Frascati manual (OECD, 2015), used for national R&D surveys.

Publication

The term publication covers the various forms of scientific publication considered in this report: papers in peer-reviewed journals and contributions to conferences with published proceedings are the two foremost forms. The authors of scientific publications are generally academic researchers, but may also be researchers in the private sector.

Scopus

An international bibliometric database produced by Elsevier. It was first launched in 2004, and now includes entries for over 22,800 journals and 150,000 books.
See: https://www.elsevier.com/solutions/scopus

Specialisation

Scientific specialisation in a given discipline means that a significant portion of an actor's (country or institution) scientific output is concentrated in this discipline, compared with a reference baseline (usually the world). The specialisation index compares the proportion of an actor's publications within a specific discipline with the average share of this discipline in all publications from the reference.

Web of Science

The Web of Science (WoS), produced by Clarivate Analytics, is an international bibliometric database and now includes entries for over 13,000 journals. OST uses the enriched WoS data to build its in-house version.
See : https://clarivate.com/products/web-of-science/

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High Council for Evaluation of Research and Higher Education (Hcéres)

Hcéres is the agency responsible for evaluating higher education and research entities in France (universities, research organisations, doctoral schools, study programmes), as well as approving the evaluation procedures implemented by other organisations. Through its analyses, evaluations and recommendations, Hcéres accompanies, advises and supports the process of continuously improving the quality of higher education and research in France.

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