InfoBrief
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Science and Engineering Publication Output Trends: 2017 Shows U.S. Output Level Slightly Below That of China but the United States Maintains Lead with Highly Cited Publications

by Karen E. White[1]

Publication output in peer-reviewed science and engineering (S&E) journals, books, and conference proceedings serves as an indicator of scientific research activity. New data show that worldwide S&E publication output continues to grow, reaching 2.4 million in 2017, with the United States and China being the two largest producers in 2017 (17% and 19% of the world total). When counted together, the European Union (EU) countries (at 26%) produced more S&E publication output than the United States or China. Globally, S&E publication output grew at an average annual rate of 4% between 2007 and 2017 (table 1). Over the same time period, the share of internationally coauthored S&E publication output also increased from 17% to 22%.

For an expanded discussion of the international publication output trends, see the *Science and Engineering Indicators* report.[2] Publication output provides insights into the development of scientific and technological capabilities around the globe. The National Center for Science and Engineering Statistics within the National Science Foundation obtained data on S&E publication output from Elsevier's Scopus database, which provides item-level information on peer-reviewed journals, books, and conference proceedings.[3]

Comparisons of Overall Scientific Publication Output

Publication Output, by Country

In 2017, the United States and China were the world's largest producers of S&E publication output, producing 424,000 and 457,000, respectively, of the 2.4 million world total. The next closest countries by count of research articles[4] were India (122,000), Germany (106,000), the United Kingdom (99,000), and Japan (98,000). Nine other countries completed the list of the top 15 countries by publication output: Italy, Russia, France, South Korea, Canada, Brazil, Spain, Australia, and Iran (table 1). These 15 countries produced just over 75% of the world's publication output in 2017.

The average annual growth rate in the number of S&E articles varied among countries. The U.S. annual growth rate of 1% was below the world's average annual growth (4%) and lower than other top producers, except for Japan (-1%) (table 1). EU countries that are among the world's largest 15 producers experienced lower than global average annual growth rates over the past 10 years: Germany (2%), the United Kingdom (1%), Italy (3%), France (1%), and Spain (3%). However, average annual growth rates were higher than the global average for Australia (4%), South Korea (5%), Brazil (7%), China (8%), Russia (9%), India (11%), and Iran (15%).

Publication Output, by Field

The distribution of S&E publication output by field provides an indication of the priority and emphasis of scientific research in different countries (table 2). On a global scale, 37% of S&E articles were in peer-reviewed journals, conference proceedings, and books classified as covering medical sciences (21%),

TABLE 1. Science and engineering articles, by country or economy: 2007 and 2017

Rank	Country or economy	2007	2017	Average annual growth rate (%)	2017 world total (%)	2017 cumulative world total (%)
-	World	1,673,077	2,422,608	3.99	100.00	-
1	China	215,755	456,960	8.43	18.86	18.86
2	United States	393,806	423,529	0.83	17.48	36.34
3	India	43,755	121,960	11.07	5.03	41.37
4	Germany	89,285	105,596	2.00	4.36	45.73
5	United Kingdom	92,720	99,297	0.97	4.10	49.83
6	Japan	109,777	97,841	-1.19	4.04	53.87
7	Italy	54,263	71,480	3.24	2.95	56.82
8	Russia	30,268	71,226	8.58	2.94	59.76
9	France	64,654	69,560	0.99	2.87	62.63
10	South Korea	41,497	62,918	5.05	2.60	65.23
11	Canada	52,640	58,997	1.62	2.44	67.67
12	Brazil	31,204	57,900	6.80	2.40	70.07
13	Spain	42,240	55,819	3.30	2.30	72.37
14	Australia	36,133	51,605	4.10	2.10	74.47
15	Iran	13,307	45,629	15.30	1.90	76.37
-	EU	511,055	631,458	2.20	26.00	-

EU = European Union.

NOTES: Articles refer to publications from a selection of peer-reviewed journals, books, and conference proceedings in science and engineering fields from Scopus. Articles are classified by their year of publication and are assigned to a region, country, or economy on the basis of the institutional addresses of the author(s) listed in the article. The region, country, or economy shown each produced 45,000 publications or more in 2017. Rankings are based on the 2017 total. Articles are credited on a fractional-count basis (i.e., for articles produced by authors from different countries, each country receives fractional credit on the basis of the proportion of its participating authors). Data are not directly comparable to *Science and Engineering Indicators 2018.* Supporting tables available upon request.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics; SRI International; Science-Metrix; Elsevier, Scopus abstract and citation database (www.scopus.com), accessed July 2018.

biological sciences (15%), or other life sciences (1%). Engineering articles made up 18% of the global output.

The S&E publication output of five major producers—the United States, the EU, China, India, and Japan—displayed distinct differences by field. In 2017, almost half (49%) of the articles from U.S. authors focused on biological sciences, medical sciences, or other life sciences, compared with 37% for the world at large. The United States also produced a higher proportion of articles in psychology (4%) and social sciences (8%) than did the world average.

As in the United States, S&E articles in the EU and Japan were focused on the fields of biological sciences, medical sciences, and other life sciences; these three fields together accounted for 40% of the EU's articles and 42% of Japan's articles. However, compared with the United States and the world, Japan had larger publication output shares in the fields of chemistry (10%) and physics (12%). China had a different pattern than the world average, with China having higher concentrations in engineering (29%) and chemistry (13%).

Another notable exception to the global averages was India's portfolio, which had a high concentration of articles in computer sciences (15%). India's proportion of research by field was also above the world average in chemistry (10%) and engineering (23%).

International Collaboration

S&E research has steadily become more global over the past decade. The percentage of worldwide S&E articles produced with international collaboration—that is, by authors from at least two countries—rose from 17% to 22% between 2007 and 2017.[5] U.S. authors experienced a similar trend of rising international collaboration, and they collaborated at a higher rate than the world average. Thirty-eight percent of S&E articles produced by authors affiliated with U.S. institutions had an international coauthor in 2017, up from 26% in 2007 (figure 1).

U.S. authors collaborated most frequently with authors from China, the largest producer of S&E articles (table 3). Researchers in China collaborated on about 24% of U.S. internationally coauthored articles in 2017. U.S. authors also had substantial collaboration with authors from the United Kingdom (13%), Germany (11%), and Canada (10%).

TABLE 2. Science and engineering research portfolios of selected country or economy, by field: 2017
(Percent)

Field	World	United States	EU	China	India	Japan
All articles (number)	2,422,608	423,529	631,458	456,960	121,960	97,841
Agricultural sciences	2.34	1.29	2.01	2.70	2.55	1.55
Astronomy	0.49	0.69	0.70	0.21	0.34	0.51
Biological sciences	15.00	17.45	14.88	13.46	14.16	15.27
Chemistry	7.88	5.03	6.57	12.61	9.83	9.58
Computer sciences	9.05	7.15	9.09	9.55	14.68	8.51
Engineering	18.49	12.44	14.55	28.55	23.30	17.40
Geosciences	5.77	4.87	5.51	6.72	6.21	3.85
Mathematics	2.47	2.06	2.54	2.05	4.71	1.86
Medical sciences	21.13	28.83	23.78	12.32	13.65	26.68
Other life sciences	1.17	2.37	1.23	0.17	0.21	0.42
Physics	8.75	6.56	8.18	10.30	8.12	12.24
Psychology	1.74	3.69	2.24	0.25	0.23	0.56
Social sciences	5.73	7.56	8.72	1.10	2.02	1.57

EU = European Union.

NOTES: Articles refer to publications from a selection of peer-reviewed journals, books, and conference proceedings in science and engineering fields from Scopus. Articles are classified by their year of publication and are assigned to a region, country, or economy on the basis of the institutional addresses of the author(s) listed in the article. Articles are credited on a fractional-count basis (i.e., for articles produced by authors from different countries, each country receives fractional credit on the basis of the proportion of its participating authors). Percentages may not add to 100% because of rounding. Data are not directly comparable to *Science and Engineering Indicators 2018.* Supporting tables available upon request.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics; SRI International; Science-Metrix; Elsevier, Scopus abstract and citation database (www.scopus.com), accessed July 2018.

Data on international collaboration of other countries (table 3) indicated that articles from authors from South Korea, China, and Canada are notable for having high collaboration rates with U.S. authors (46%, 45%, and 43%, respectively).

Scientific Impact

Publication data can be used to indicate scientific impact by counting how many times an article is cited in another journal article, conference proceeding, or book. Those with more citations can be said to be more impactful to the scientific discipline. A small subset within the cited articles receives a high number of citations—highly cited articles—which are articles that are most frequently cited within other researchers' papers, conference proceedings, and books; this InfoBrief presents data on the top 1% most cited articles.

The United States contributed nearly twice the expected volume of highly cited articles in 2015 (highly cited articles [HCA] score of 1.9) (figure 2). China's highly cited articles exceeded its expected share (HCA score of 1.1), and Japan and India were each below their expected levels in 2015 (HCA scores of 0.8 and 0.7, respectively).

HCA scores have changed over time. The HCA score of the United States increased slightly from 1.8 in 2005 to 1.9 in 2015. The share of Chinese articles among the top 1% most cited articles doubled over the same decade, with HCA scores of 0.5 in 2005 and 1.1 in 2015. In 2005, India's scientific impact was similar to China's; yet India's HCA score remained relatively flat while China's rose. HCA scores for Japan increased over the past 10 years, from 0.6 in 2005 to 0.8 in 2015. The HCA score for China roughly equaled that of Japan in 2011; however, China's score surpassed Japan's in 2012.

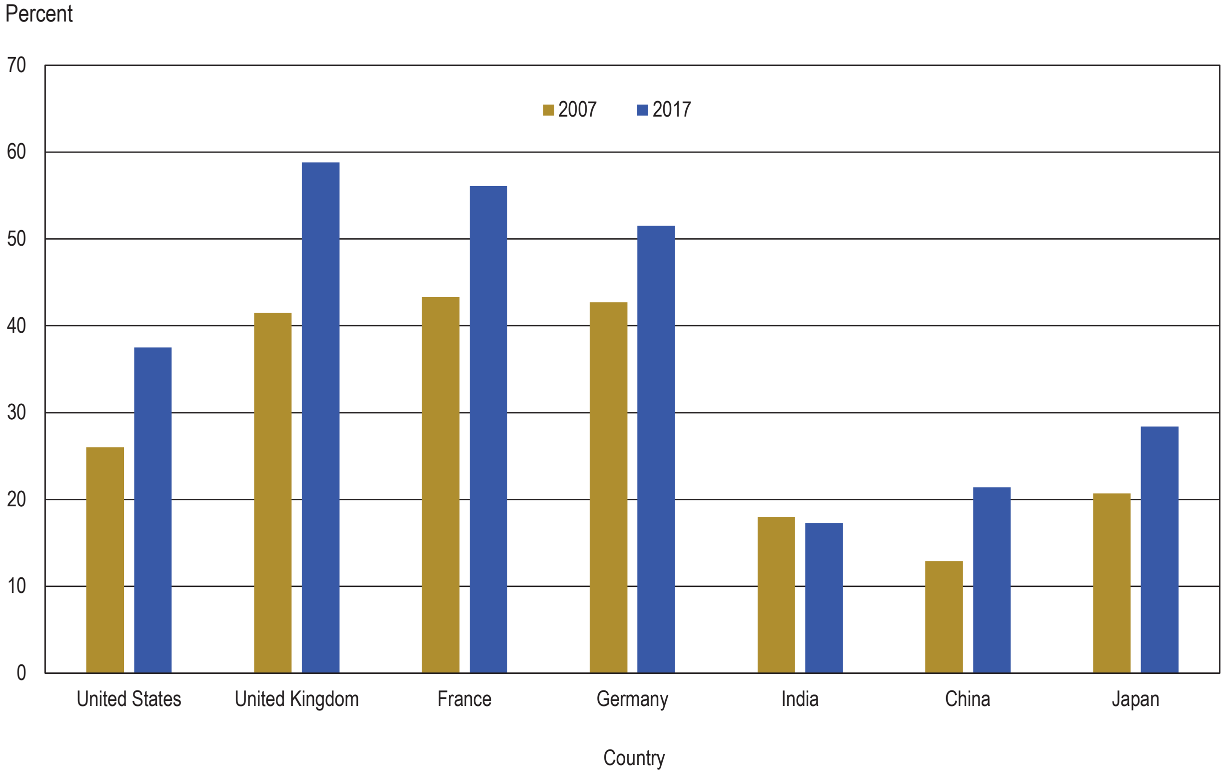
The EU's HCA score increased from 1.1 in 2005 to 1.3 in 2015, driven by the growth of impactful research from several member countries, such as the United Kingdom.

Data Sources and Limitations

This InfoBrief derives the counts, coauthorships, and citations from information about research materials in S&E fields published in peer-reviewed scientific and technical journals, books, and conference proceedings (articles) collected in Elsevier's Scopus database.

This InfoBrief uses the same set of filters described in the technical documentation from *Science and Engineering Indicators 2018.*[6] The documentation also includes discus-

FIGURE 1. Science and engineering articles internationally coauthored, by country: 2007 and 2017



NOTES: Articles refer to publications from a selection of peer-reviewed journals, books, and conference proceedings in science and engineering fields from Scopus. Articles are classified by their year of publication and are assigned to a region, country, or economy on the basis of the institutional addresses of the authors listed in the article. Articles are credited on a whole-count basis (i.e., each region, country, or economy with a collaborating author on an article is credited with one count). Data are not directly comparable to *Science and Engineering Indicators 2018.* Supporting tables available upon request.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics; SRI International; Science-Metrix; Elsevier, Scopus abstract and citation database (www.scopus.com), accessed July 2018.

sions on the various measures used in the InfoBrief. In addition, Scopus is a dynamic database where articles, especially conference proceedings, may enter the database with some delay. The upcoming *Science and Engineering Indicators* report will update the publication output data through 2018. Additional data and supporting tables are available from the author upon request.

Methodology

Number of Articles, Using Whole Counting and Fractional Counting

Article counts are the number of peer-reviewed S&E articles produced by a given country, region, or economy. Articles coauthored by multiple countries are counted in two ways. With fractional counting, a country receives partial credit for an article in proportion to the number of authors with institutional addresses from that country. Fractional counting enables the country article counts to sum up to the world total number of articles (tables 1 and 2). Whole counting (also called full or integer counting) assigns one count to each country involved in authoring or coauthoring the article, irrespective of their proportionate contribution to authorship (table 3 and figures 1 and 2).

This InfoBrief focuses on research output in the form of articles, which includes publications from a selection of peer-reviewed S&E journals, books, and conference proceedings. Fractional counting is the appropriate measure for comparing the proportionate contributions of countries to an article. On the other hand, whole counting measures a country's participation or involvement. Assigning each country a count of 1 for each coauthor country yields different results. For example, if there are 3 coauthors (1 Canadian and 2 U.S.) Canada would get 1 credit and the U.S. would get 1 credit. Whole counting articles by coauthors' country shows China's 2017 publication output was 505,779, while the U.S. publication output was 541,193.

TABLE 3. International coauthorship of science and engineering articles with the United States, by world and selected country: 2017

(Percent)

World or country	Share of world's or country's international articles coauthored with the United States	Share of U.S. international articles coauthored with country
World	38.1	-
China	45.2	24.1
United Kingdom	28.9	13.4
Germany	28.6	11.1
Canada	43.4	10.2
France	25.0	7.3
Italy	28.1	6.5
Japan	32.7	5.4
Australia	28.3	6.4
South Korea	45.7	4.7
Spain	24.5	4.9
Netherlands	30.3	4.7
Switzerland	32.4	4.6
Brazil	35.9	4.0
India	30.9	3.5
Sweden	28.8	3.3

NOTES: Articles refer to publications from a selection of peer-reviewed journals, books, and conference proceedings in science and engineering fields from Scopus. Articles are classified by their year of publication and are assigned to a region, country, or economy on the basis of the institutional addresses of the authors listed in the article. Articles are credited on a whole-count basis (i.e., each region, country, or economy with a collaborating author on an article is credited with one count). Data are not directly comparable to *Science and Engineering Indicators 2018.* Supporting tables available upon request.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics; SRI International; Science-Metrix; Elsevier, Scopus abstract and citation database (www.scopus.com), accessed July 2018.

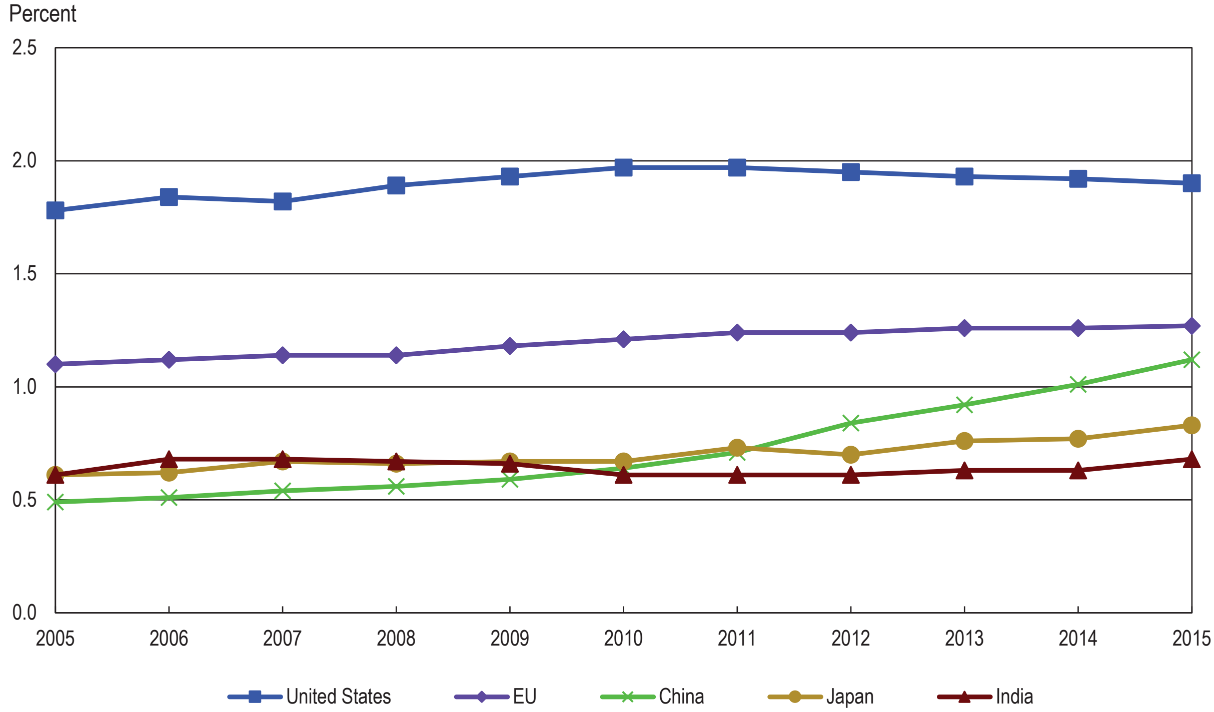
Timeliness of the Citation-Based Measures

For all citation-based measures, a certain amount of time must be allowed for the published work to have an impact on subsequent research because of the delay between the appearance of an article and its being read, understood, and taken up in subsequent research. Normally, a window of at least 2 years is allowed, although allowing a window of 3 years generally facilitates measurements that more robustly reflect long-term trends; the 3-year window has been applied here. Accordingly, impact assessments for this InfoBrief cover articles appearing in 2015 or earlier. In an effort to analyze as much data as possible, citation data for 2015 articles have citation windows ranging from 24 to 36 months, depending on the month in which an article was released.

Highly Cited Articles Score Computation

An HCA score is not a perfect measure of impact,[7] but it does provide a rough indication of scientific impact. To create the HCA score we first created a dataset of the top 1% most cited publications in each field and for each year. The HCA score for a country is the share of authors with institutional addresses within that country who have articles that are among the top 1% of the world's highly cited articles, relative to all the articles ascribed to that country. The HCA score is indexed to 1, so that a country's authors producing highly cited articles at the expected (i.e., global average) rate has an HCA score of 1—that is, 1% of the country's articles are among the top 1% of the world's highly cited articles. Countries' authors producing highly cited articles at greater than the expected rate have HCA scores greater than 1, and countries' authors producing impactful articles at lower than the expected rate have HCA scores below 1. For example, assume the world output was 10,000 articles and there were two countries, with country x authors producing 7,000 articles and country y authors producing 3,000 articles. If both countries had the same impact in the citation records, then country x would have 70 highly cited articles and country y would have 30 highly cited articles in the top 100 most cited articles in the world. Each country would have an HCA score of 1. The scores would be different if authors in one of the countries produced a higher proportion of the highly cited articles. For example, if authors in country y produced 50 of the most highly cited articles, then their HCA score would be 1.7, indicating that 1.7% of the articles of country y's authors (50 out of 3,000) are among the top 1% of the world's highly cited articles. For country x, its HCA would be 0.7 (50 out of 7,000).

FIGURE 2. Science and engineering articles that are in the top 1% of cited articles, by selected country or economy: 2005–15



EU = European Union.

NOTES: Highly cited articles are those that are most frequently cited by other researchers in their articles; for this study, the top 1% most cited articles in the world were selected in each field and for each year. The share of articles produced by a country that are among these top 1% most cited articles in the world, relative to all that country's articles, constitutes the country's highly cited articles (HCA) score. It is computed as follows: *Sx = HCAx/Px,* where *Sx* is the share of output from country *x* in the world's top 1% most cited articles; *HCAx* is the number of articles from country *x* that are among the top 1% most cited articles in the world; and *Px* is the total number of published articles from country x. Citations are presented for the year of publication, showing the counts of subsequent citations from peer-reviewed literature. At least 3 years of data following publication are needed for a meaningful measure. Articles that cannot be classified by country or field are excluded. Articles are classified by their year of publication and are assigned to a region, country, or economy on the basis of the institutional addresses of the author(s) listed in the article. The world average HCA scores stands at 1.00% for each period and field. Data are not directly comparable to *Science and Engineering Indicators 2018.* Supporting tables available upon request.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics; SRI International; Science-Metrix; Elsevier, Scopus abstract and citation database (www.scopus.com), accessed July 2018.

Notes

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2. National Science Board. 2018. *Science and Engineering Indicators 2018.* NSB-2018-1. Alexandria, VA: National Science Foundation. Available at https://www.nsf.gov/statistics/indicators/.

3. More information on the selection of documents can be found at https://www.elsevier.com/solutions/scopus.

4. Articles refer to publication output from a selection of peer-reviewed journals, books, and conference proceedings in science and engineering fields from Scopus.

5. Special tabulation for share of internationally coauthored S&E articles is available upon request from the author.

6. Science-Metrix. 2017. Bibliometric and patent indicators for the Science and Engineering Indicators 2018. Technical documentation. Montreal, Canada: Science-Metrix. http://www.science-metrix.com/en/methodology-report.

7. Waltman L, van Eck N, and Wouters P. Counting publications and citations: Is more always better? https://arxiv.org/ftp/arxiv/papers/1301/1301.4597.pdf.