Research Fronts 2018: Active Fields, Leading Countries

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Science and technology are universal and epochal, and the development of science and technology must be viewed from a global perspective. At present, major breakthroughs and accelerated applications of technological innovation have been instrumental in reshaping the global economic structure and transforming the arena of industrial and economic competition. The "Research Fronts 2018" report is a prequel to "Research Fronts 2018: Active Fields, Leading Countries" report, having selected and discussed 100 hot fronts and 38 emerging fronts in 10 broad research areas. Based on the finding of "Research Fronts 2018", the report of "Research Fronts 2018: Active Fields, Leading Countries" uses the Research Leadership Index to assess the research activity of the world's major countries and to observe how that activity, in the face of global competition in innovation and technological advancement, is demonstrated in these Research Fronts.

1 Methodology

1.1 The logic model of Research Leadership Index (RLI)

The Research Leadership Index (RLI) is a comprehensive evaluation index to measure the activity and dynamics of Research Fronts. Since a Research Front itself is composed of a group of highly cited core papers along with citing papers that repeatedly reference the core reports, the design of the Research Leadership Index considers both the numbers of the core papers and citing papers, and the citations of the core papers and citing papers. Two indicators of Output Share and Citation Share are designed. The logical model of RLI is shown in Figure 1.
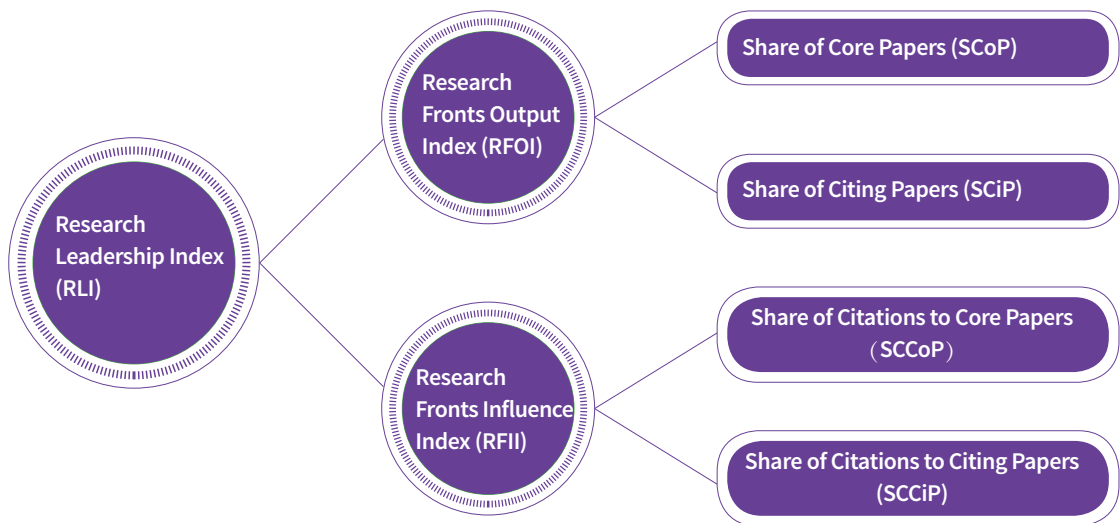

Fig. 1. The logic model of Research Leadership Index (RLI)

The RLI can be applied to measure the performance of countries, cities, institutions, laboratories, teams, and individual scientists. Each unit can be measured at three levels: Research Front level, area level, and at the level of all 10 broad research areas.

1.2 Research Leadership Index of a country (RLI$_C$)

This report calculates the Research Leadership Index of main countries at Research Front level, area level, and all 10 broad research areas level. Based on the analysis, we reveal the innovation activity degree and its pattern of the main countries in Research Fronts and uncover the sources of research vitality in various countries. The methods of calculation and analysis are as follows:

1.2.1 Research Leadership Index of a country in a Research Front (RLI$_{Cij}$)

The Research Leadership Index is a comprehensive evaluation index to measure the activity degree of a country in Research Fronts, including two aspects of the output and citation influence of papers in the Research Fronts. The equation of Research Leadership Index of Country in a Research Front (RLI$_{Cij}$) is as follows:

$$RLI_{Cij} = RFOI_{Cij} + RFII_{Cij} = \frac{CoP_{ij}}{CoP_j} + \frac{CiP_{ij}}{CiP_j} + \frac{CoC_{ij}}{CoC_j} + \frac{CiC_{ij}}{CiC_j}$$

RFOI$_{Cij}$ is the Research Fronts Output Index of a country, while RFII$_{Cij}$ is the research Fronts Influence Index of a country, with j representing the Research Front, and i representing each country.

(1) Research Fronts Output Index of a country (RFOI$_{Cij}$)

Research Fronts Output Index of a country (RFOI$_{Cij}$) is the relative share of the number of papers (core papers and citing papers) contributed by a country in a Research Front. RFOI$_{Cij}$ equals the sum of the two indicators SCoP$_{Cij}$ and SCiP$_{Cij}$

$$RFOI_{Cij} = SCoP_{Cij} + SCiP_{Cij} = \frac{CoP_{ij}}{CoP_j} + \frac{CiP_{ij}}{CiP_j}$$

A country's share of core papers in a Research Front (SCoP$_{Cij}$) indicates the percentage of CoP_{ij} in CoP_j.

$$SCoP_{Cij} = \frac{CoP_{ij}}{CoP_j}$$

CoP_{ij} represents the number of core papers published by country in Research Front j; CoP_j represents the number of core papers in Research Front j.

A country's share of citing paper in a Research Front (SCiP$_{Cij}$) indicates the percentage of CiP_{ij} in CiP_j.

$$SCiP_{Cij} = \frac{CiP_{ij}}{CiP_j}$$

CiP_{ij} represents the number of citing papers published by country i in Research Front j; CiP_j represents the number of citing papers in Research Front j.

(2) Research Fronts Influence Index of a country (RFII$_{Cij}$)

The Research Fronts Influence Index of a country (RFII$_{Cij}$) is the relative share of the citation of papers (core papers and citing papers) of a country contributed in a Research Front. The RFII$_{Cij}$ equals the sum of the two indicators SCCoP$_{Cij}$ and SCCiP$_{Cij}$.

$$RFII_{Cij} = SCCoP_{Cij} + SCCiP_{Cij} = \frac{CoC_{ij}}{CoC_j} + \frac{CiC_{ij}}{CiC_j}$$

A country's share of citations to core papers for a Research Front (SCCoP$_{Cij}$) indicates the percentage of CoC_{ij} in CoC_j.

$$SCCoP_{Cij} = \frac{CoC_{ij}}{CoC_j}$$

CoC_{ij} represents the citation of core papers published by country i in Research Front j; CoC_j represents the citation of core papers in Research Front j.

A country's share of citations to citing papers in a Research Front (SCCiP$_{Cij}$) indicates the percentage of CiC_{ij} in CiC_j.

$$SCCiP_{Cij} = \frac{CiC_{ij}}{CiC_j}$$

CiC_{ij} represents the citations of citing papers published by country i in Research Front j; CiC_j represents the citations of citing papers in Research Front j.

1.2.2 Research Leadership Index of a country in an area (RLI$_{Cik}$)

The Research Leadership Index of country i in area k (RLI$_{Cik}$) is the summation of the Research Leadership Index of country i (RLI$_{Cij}$) in n Research Fronts in area k. k is the one area, n is the total number of areas.

The formula of RLI$_{Cik}$ is as follow:

$$\text{RLI}_{ik} = \text{RFOI}_{Cik} + \text{RFII}_{Cik} == \sum_{j=1}^{n} \frac{CoP_{ij}}{CoP_j} + \sum_{j=1}^{n} \frac{CiP_{ij}}{CiP_j} + \sum_{j=1}^{n} \frac{CoC_{ij}}{CoC_j} + \sum_{j=1}^{n} \frac{CiC_{ij}}{CiC_j}$$

RLI$_{Cik}$ equals the sum of the two indicators RFOI$_{Cik}$ and RFII$_{Cik}$.

(1) Research Fronts Output Index of a country in an area (RFOI$_{Cik}$)

The Research Fronts Output Index of a country in an area (RFOI$_{Cik}$) is the relative share of the number of papers (core papers and citing papers) contributed by a country to an area composed of n Research Fronts. RFOI$_{Cik}$ equals the sum of the two indicators SCoP$_{Cik}$ and SCiP$_{Cik}$.

$$\text{RFOI}_{Cik} = \text{SCoP}_{Cik} + \text{SCiP}_{Cik} = \sum_{j=1}^{n} \frac{CoP_{ij}}{CoP_j} + \sum_{j=1}^{n} \frac{CiP_{ij}}{CiP_j}$$

The formula of a country's share of core papers in an area (SCoP$_{Cik}$) is as follows:

$$\text{SCoP}_{Cik} = \sum_{j=1}^{n} \frac{CoP_{ij}}{CoP_j}$$

The formula of a country's share of citing papers in an area (SCiP$_{Cik}$) is as follows:

$$\text{SCiP}_{Cik} = \sum_{j=1}^{n} \frac{CiP_{ij}}{CiP_j}$$

(2) Research Fronts Influence Index of a country in an area (RFII$_{Cik}$)

The Research Fronts Influence Index of a country in an area (RFII$_{Cik}$) is the relative share of the citation of papers (core papers and citing papers) contributed by a country to an area composed of n Research Fronts. RFII$_{Cik}$ equals the sum of the two indicators SCCoP$_{Cik}$ and SCCiP$_{Cik}$.

$$\text{RFII}_{Cik} = \text{SCCoP}_{Cik} + \text{SCCiP}_{Cik} = \sum_{j=1}^{n} \frac{CoC_{ij}}{CoC_j} + \sum_{j=1}^{n} \frac{CiC_{ij}}{CiC_j}$$

The formula of a country's share of citations to core papers in an area (SCCoP$_{Cik}$) is as follows:

$$\text{SCCoP}_{Cik} = \sum_{j=1}^{n} \frac{CoC_{ij}}{CoC_j}$$

The formula of a country's share of citations to citing papers in an area (SCCiP$_{Cik}$) is as follows:

$$\text{SCCiP}_{Cik} = \sum_{j=1}^{n} \frac{CiC_{ij}}{CiC_j}$$

1.2.3 Research Leadership Index of a country in 10 broad research areas (RLI$_{Ci}$)

The Research Leadership Index of a country in 10 broad research areas (RLI$_{Ci}$) is the scores of RLI$_{Cik}$ of 10 broad research areas added together. The index is a comprehensive evaluation index to measure the degree of activity of a country in contributing to 10 broad research areas comprising 138 Research Fronts.

$$\text{RLI}_{Ci} = \text{RFOI}_{Ci} + \text{RFII}_{Ci}$$
$$= \sum_{k=1}^{10} \sum_{j=1}^{n} \frac{CoP_{ij}}{CoP_j} + \sum_{k=1}^{10} \sum_{j=1}^{n} \frac{CiP_{ij}}{CiP_j} + \sum_{k=1}^{10} \sum_{j=1}^{n} \frac{CoC_{ij}}{CoC_j} + \sum_{k=1}^{10} \sum_{j=1}^{n} \frac{CiC_{ij}}{CiC_j}$$

RLI$_{Ci}$ equals the sum of the two indicators RFOI$_{Ci}$ and RFII$_{Ci}$.

(1) Research Fronts Output Index of a country in 10 broad research areas (RFOI$_{Ci}$)

The Research Fronts Output Index of a country in 10 broad research areas (RFOI$_{Ci}$) is the sum of the relative share of the number of papers (core papers and citing papers) contributed by a country to 10 broad research areas comprising 138 Research Fronts. RFOI$_{Ci}$ equals the sum of the two indicators SCoP$_{Ci}$ and SCiP$_{Ci}$.

$$\text{RFOI}_{Ci} = \text{SCoP}_{Ci} + \text{SCiP}_{Ci} = \sum_{k=1}^{10} \sum_{j=1}^{n} \frac{CoP_{ij}}{CoP_j} + \sum_{k=1}^{10} \sum_{j=1}^{n} \frac{CiP_{ij}}{CiP_j}$$

The formula of a country's share of core papers in 10 broad research areas (SCoP$_{Ci}$) is as follows:

$$\text{SCoP}_{Ci} = \sum_{k=1}^{10} \sum_{j=1}^{n} \frac{CoP_{ij}}{CoP_j}$$

The formula of a country's share of citing papers in 10 broad research areas (SCiP$_{Ci}$) is as follows:

$$\text{SCiP}_{Ci} = \sum_{k=1}^{10} \sum_{j=1}^{n} \frac{CiP_{ij}}{CiP_j}$$

(2) Research Fronts Influence Index of a country in 10 broad research areas (RFII$_{Ci}$)

The Research Fronts Influence Index of a country in 10 broad research areas (RFII$_{Ci}$) is the sum of the relative share of the citations of papers (core papers and citing papers) of a country contributing to 10 broad research areas composed 138 Research Fronts. RFII$_{Ci}$ equals the sum of the two indicators SCCoP$_{Ci}$ and SCCiP$_{Ci}$.

$$\text{RFII}_{Ci} = \text{SCCoP}_{Ci} + \text{SCCiP}_{Ci} = \sum_{k=1}^{10} \sum_{j=1}^{n} \frac{CoC_{ij}}{CoC_j} + \sum_{k=1}^{10} \sum_{j=1}^{n} \frac{CiC_{ij}}{CiC_j}$$

The formula of a country's share of citations to core papers in 10 broad research areas (SCCoP$_{Ci}$) is as follows:

$$\text{SCCoP}_{Ci} = \sum_{k=1}^{10} \sum_{j=1}^{n} \frac{CoC_{ij}}{CoC_j}$$

The formula of a country's share of citations to citing papers in 10 broad research areas (SCCiP$_{Ci}$) is the following:

$$\text{SCCiP}_{Ci} = \sum_{k=1}^{10} \sum_{j=1}^{n} \frac{CiC_{ij}}{CiC_j}$$

2 Analysis of the RLI$_{ci}$ of Top countries

> We measure the RLI$_{ci}$ of main countries in 10 broad research areas represented by 138 Research Fronts, and rank the Top countries. The following phenomena were observed.

2.1 The USA remains the most active, and China's score is unchanged from last year

For 10 broad research areas with 138 Research Fronts, the USA is the most active, with an RLI$_{ci}$ score of 227.39, ranking 1st. China ranks 2nd with a score of 118.38. The UK and Germany score 78.62 and 75.12 respectively, ranking 3rd and 4th, but they also drop significantly compare to their 2017 performance. The two countries score close together in the same active grade.

The RLI$_{ci}$ scores of France, Italy, Canada, Spain, Australia, Netherlands, Switzerland and Japan all register at between roughly 30 to 50, ranking 5th to 12th. The RLI$_{ci}$ of Japan is 27.86, ranking 12th. While Sweden ranks 13th, scoring 19.11, there is a big gap between these two countries. The countries ranking 13rd to 20th, score in the range of 12.26 to 19.11.
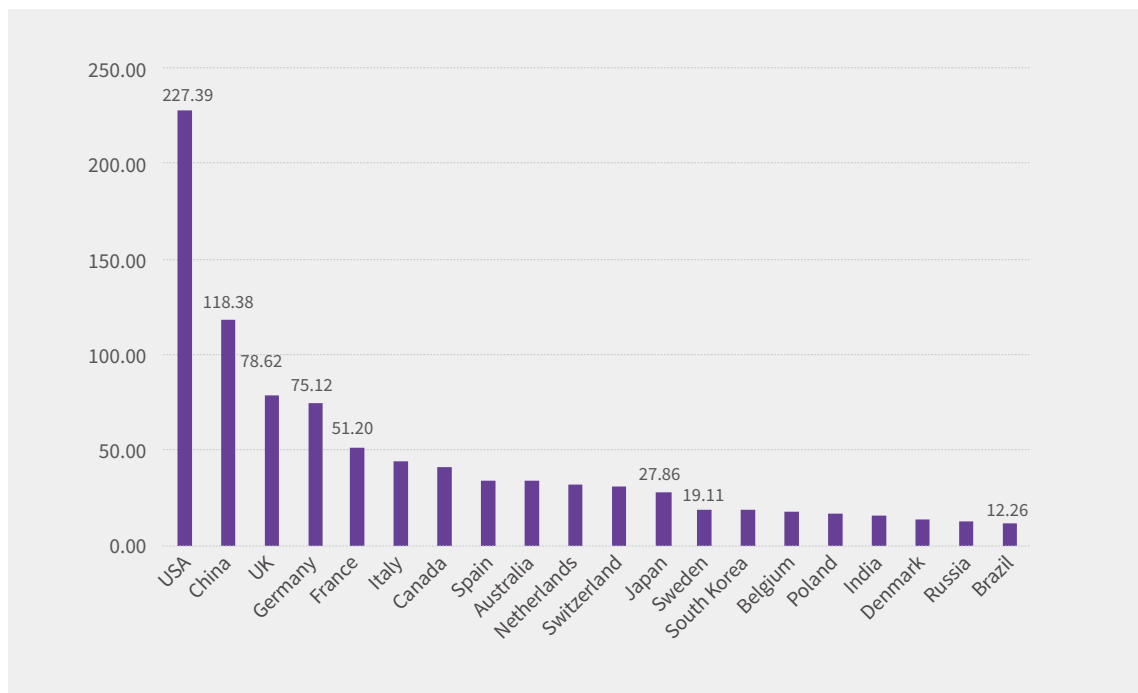

Fig 2. Research Leadership Index (RLI$_{ci}$) of Top20 Countries in 10 broad research areas with 138 Research Fronts

Table 1 shows that the ranks based on the three indicators RLI_{ci}, $RFOI_{ci}$ and $RFII_{ci}$ for the top seven countries are exactly the same. The three indicators for the countries that between 8th and 20th basically coincide, but the ranking is slightly different.

Table 1. Research Leadership Index (RLI_{ci}) of Top 20 Countries in 10 broad research areas comprising 138 Research Fronts

	RLI_{ci}		$RFOI_{ci}$		$RFII_{ci}$	
	Score	Rank	Score	Rank	Score	Rank
USA	227.39	1	119.88	1	107.51	1
China	118.38	2	69.36	2	49.02	2
UK	78.62	3	41.01	3	37.61	3
Germany	75.12	4	38.49	4	36.63	4
France	51.20	5	25.74	5	25.46	5
Italy	44.58	6	23.40	6	21.18	6
Canada	41.65	7	21.64	7	20.01	7
Spain	34.64	8	17.16	9	17.48	8
Australia	34.33	9	18.12	8	16.21	10
Netherlands	32.40	10	15.64	10	16.77	9
Switzerland	30.74	11	14.94	12	15.80	11
Japan	27.86	12	15.09	11	12.77	12
Sweden	19.11	13	9.53	14	9.57	14
South Korea	18.66	14	9.74	13	8.92	15
Belgium	18.32	15	8.56	16	9.77	13
Poland	16.76	16	8.30	17	8.47	16
India	16.08	17	9.20	15	6.88	19
Denmark	14.34	18	6.54	18	7.80	17
Russia	13.07	19	6.17	20	6.90	18
Brazil	12.26	20	6.39	19	5.87	20

2.2 The USA leads in activity for all areas. China's activity in several area is elevated, but there are still low-lying areas

The USA's RLI_{ci} places it first in eight of the 10 broad research areas, expect for two areas. By contrast, China ranks 1st in two areas: Chemistry and Materials Science, and Mathematics, Computer Science and Engineering. China ranks 2nd to 3rd in four areas: Agricultural, Plant and Animal Sciences, Ecology and Environmental Science, Geosciences, and Physics. The country ranks 4th in Biological Science and Economics, Psychology and Other social sciences. At the same time, however, China's rank in the fields of Clinical Medicine and Astronomy and Astrophysics is 13th and 19th, respectively.

Table 2. The score and rank of RLI$_{Ci}$ and RLI$_{Clk}$ of Top 20 Countries

Countries	10 broad research areas		Agricultural, Plant and Animal Sciences		Ecology and Environmental Science		Geosciences		Clinical Medicine		Biological Sciences		Chemistry and Materials science		Physics		Astronomy and Astrophysics.		Mathematics, Computer Science and Engineering		Economics, Psychology and Other Social Sciences	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
USA	227.39	1	15.33	1	14.07	1	21.49	1	41.44	1	38.73	1	22.37	2	17.55	1	26.54	1	5.15	2	24.73	1
China	118.38	2	8.07	2	11.82	2	9.93	2	5.58	13	9.08	4	28.66	1	6.12	3	4.22	19	31.52	1	3.40	4
UK	78.62	3	4.10	5	4.24	4	6.41	4	14.60	3	10.58	2	4.37	4	5.71	4	17.86	2	3.17	3	7.59	2
Germany	75.12	4	6.39	3	3.84	5	4.35	6	17.96	2	10.31	3	5.94	3	8.05	2	15.48	3	0.48	16	2.33	9
France	51.20	5	4.42	4	4.53	3	7.43	3	10.16	4	5.02	6	2.44	7	3.49	9	10.43	4	2.01	8	1.26	12
Italy	44.58	6	3.59	7	3.05	8	0.62	26	9.85	5	8.17	5	1.20	14	4.29	5	9.18	7	2.83	5	1.80	10
Canada	41.65	7	2.23	11	2.33	12	4.45	5	7.90	6	4.56	8	2.03	9	3.72	8	9.40	6	2.49	6	2.54	7
Spain	34.64	8	3.81	6	2.34	11	1.08	16	7.67	8	2.36	14	1.14	15	3.47	10	10.01	5	0.20	24	2.57	6
Australia	34.33	9	1.89	14	3.83	6	3.33	7	7.71	7	2.72	12	1.64	12	1.18	20	4.64	16	3.12	4	4.28	3
Netherlands	32.40	10	2.89	8	3.38	7	1.08	17	6.60	9	4.48	9	0.89	17	2.51	12	8.15	8	0.03	48	2.41	8
Switzerland	30.74	11	2.56	9	2.38	10	1.51	13	6.18	10	4.67	7	1.11	16	3.85	7	6.92	10	0.04	44	1.51	11
Japan	27.86	12	2.26	10	0.64	26	2.04	9	5.83	11	2.45	13	2.22	8	2.56	11	7.64	9	1.70	9	0.51	17
Sweden	19.11	13	1.51	15	2.51	9	1.66	12	3.55	15	3.20	10	1.82	10	0.98	22	3.04	25	0.14	28	0.69	15
South Korea	18.66	14	1.40	16	0.78	23	0.90	21	3.17	18	0.86	23	3.69	5	2.44	13	2.71	26	2.38	7	0.32	23
Belgium	18.32	15	2.07	13	1.17	19	1.92	10	3.44	16	3.17	11	0.31	27	0.54	30	3.06	23	0.04	41	2.60	5
Poland	16.76	16	0.84	21	1.25	18	0.39	30	5.58	12	0.74	25	0.50	22	1.63	15	4.92	13	0.64	15	0.26	29
India	16.08	17	0.88	20	1.08	20	1.05	18	1.43	26	0.94	21	1.70	11	2.24	14	5.36	12	1.07	11	0.33	22
Denmark	14.34	18	0.32	33	1.31	17	0.84	22	4.46	14	0.61	29	0.10	37	0.32	34	6.03	11	0.01	64	0.36	20
Russia	13.07	19	0.33	31	0.38	30	1.47	14	1.54	25	0.27	35	0.59	21	3.93	6	4.40	17	0.15	27	0.01	53
Brazil	12.26	20	1.31	17	0.71	25	0.75	24	3.24	17	1.21	19	0.16	31	1.40	17	2.54	27	0.07	35	0.86	14

Among the 100 hot Research Fronts and 38 emerging Research Fronts in 10 broad research areas, the USA ranks first in 82 fronts, accounting for 59.42% of the total of 138. China #1 ranking in 32 fronts, or 23.19%. The UK and Germany, meanwhile, rank first in only four and six and Research Fronts, respectively (Table 3).

For 10 broad research areas, Mathematics, Computer Science and Engineering, and Chemistry and Materials Science are the two most advanced areas for China, with the nation ranking first in more than 50% Research Fronts in those fields. Actually, in the area of Mathematics, Computer Science and Engineering, China registers at #1 in 91.67% of the pertinent Research Fronts. China ranks first in four Research Fronts in the area Ecology and Environmental Science, and in two Research Fronts in the area Agricultural, Plant and Animal Sciences and Geoscience, respectively. In

the following four areas: Clinical Medicine, Biological Science, and Physics, Economics, Psychology and Other Social Sciences, China ranks first in one Research Front. Meanwhile, there are no Research Fronts in the field of Astronomy and Astrophysics in which China ranks first.

In contrast to China, the USA has no top ranking in the field of Mathematics, Computer Science and Engineering, while it ranks first in only 33.33% of the Research Fronts in Chemistry and Materials Science. These two areas are highly active for China. In the following five areas of Clinical Medicine, Biological Science, Physics, Astronomy and Astrophysics, and Economics, Psychology and Other Social Sciences, the USA can claim the #1 ranking in 70% of the Research Fronts. In the areas of Agricultural, Plant and Animal Sciences, Ecology and Environmental Sciences, and Geoscience, the USA ranks first in roughly half the fronts, which is the best among all countries.

Table 3. The numbers and ratios for the Top 5 countries ranking first in 10 broad research areas comprising 138 Research Fronts (based on RLI_{ci})

Areas	Numbers of RFs	Numbers of ranking 1st RFs					Ratios				
		USA	China	UK	Germany	Italy	USA	China	UK	Germany	Italy
10 broad research areas total	138	82	32	4	6	4	59.42%	23.19%	2.90%	4.35%	2.90%
Agricultural, Plant and Animal Sciences	11	6	2	1	1	0	54.55%	18.18%	9.09%	9.09%	0.00%
Ecology and Environmental Sciences	11	5	4	0	0	0	45.45%	36.36%	0.00%	0.00%	0.00%
Geosciences	11	7	2	0	0	0	63.64%	18.18%	0.00%	0.00%	0.00%
Clinical Medicine	21	17	1	0	2	0	80.95%	4.76%	0.00%	9.52%	0.00%
Biological Sciences	20	15	1	0	1	3	75.00%	5.00%	0.00%	5.00%	15.00%
Chemistry and Materials Science	18	6	9	0	1	0	33.33%	50.00%	0.00%	5.56%	0.00%
Physics	11	9	1	1	0	0	81.82%	9.09%	9.09%	0.00%	0.00%
Astronomy and Astrophysics	12	9	0	1	1	0	75.00%	0.00%	8.33%	8.33%	0.00%
Mathematics, Computer Science and Engineering	12	0	11	0	0	1	0.00%	91.67%	0.00%	0.00%	8.33%
Economics, Psychology and Other Social Sciences	11	8	1	1	0	0	72.73%	9.09%	9.09%	0.00%	0.00%

For the Research Fronts rank in the Top 3, the USA has 118 (85.51%) , China, the UK and Germany have 54, 44 and 40, respectively (accounting for nearly 1/3 or more

of the total number of Research Fronts in one's own country) (Table 4).

Table 4. The numbers and ratios of the ranking Top 3 Research Fronts for the Top 6 countries in 10 broad research areas with 138 Research Fronts (based on RLI_{ci})

Areas	Numbers of RFs	Numbers of ranking Top 3 RFs						Ratios					
		USA	China	UK	Germany	Italy	France	USA	China	UK	Germany	Italy	France
10 broad research areas total	138	118	54	44	40	13	22	85.51%	39.13%	31.88%	28.99%	9.42%	15.94%
Agricultural, Plant and Animal Sciences	11	9	5	1	4	3	3	81.82%	45.45%	9.09%	36.36%	27.27%	27.27%
Ecology and Environmental Sciences	11	10	5	2	1	1	4	90.91%	45.45%	18.18%	9.09%	9.09%	36.36%
Geosciences	11	10	5	3	1	0	5	90.91%	45.45%	27.27%	9.09%	0.00%	45.45%
Clinical Medicine	21	20	1	7	9	3	3	95.24%	4.76%	33.33%	42.86%	14.29%	14.29%
Biological Sciences	20	18	7	7	6	4	1	90.00%	35.00%	35.00%	30.00%	20.00%	5.00%
Chemistry and Materials Science	18	15	16	3	4	0	2	83.33%	88.89%	16.67%	22.22%	0.00%	11.11%
Physics	11	11	2	3	6	0	1	100.00%	18.18%	27.27%	54.55%	0.00%	9.09%
Astronomy and Astrophysics	12	11	0	7	7	0	1	91.67%	0.00%	58.33%	58.33%	0.00%	8.33%
Mathematics, Computer Science and Engineering	12	5	11	3	1	1	2	41.67%	91.67%	25.00%	8.33%	8.33%	16.67%
Economics, Psychology and Other Social Sciences	11	9	2	10	1	1	0	81.82%	18.18%	90.91%	9.09%	9.09%	0.00%

In terms of the 10 research areas, the USA has 80%-100% of the fronts rank in the Top 3 in nine areas. In Chemistry and Materials Science, the USA has 83.33% ranks in the Top 3. But the USA also has the lowest percent in Mathematics, Computer Science and Engineering science, with 41.67% Research Fronts rank the Top 3.

Comparatively speaking, China's performance in the two areas of Chemistry and Materials Science and Mathematics, Computer Science and Engineering is impressive. China scores 16 (88.89%) and 11 (91.67%) of the Top 3 Research Fronts in these two areas. In Biological Sciences, China has seven Research Fronts in the Top 3. Despite a percent of only 35%, China also performs well in this area. In the following three areas of Agricultural, Plant and Animal Sciences, Ecology and environmental sciences, and Geosciences, China gains five Research Fronts rank in the Top 3, accounting for 45.45% in each area.

We observe that China's performances in several areas are elevated, but there are still low-lying areas. China is the most active in two areas: Chemistry and Materials Science and Mathematics, Computer Science and Engineering. In Agricultural, Plant and Animal Sciences, Ecology and Environmental Science, and Geosciences, China has been already quite active in some Research Fronts. Greater effort must be made in Physics, Economics, Psychology and Other Social Sciences, and Biological Sciences. The activities in the areas of Clinical Medicine and Astronomy and Astrophysics are obviously insufficient.
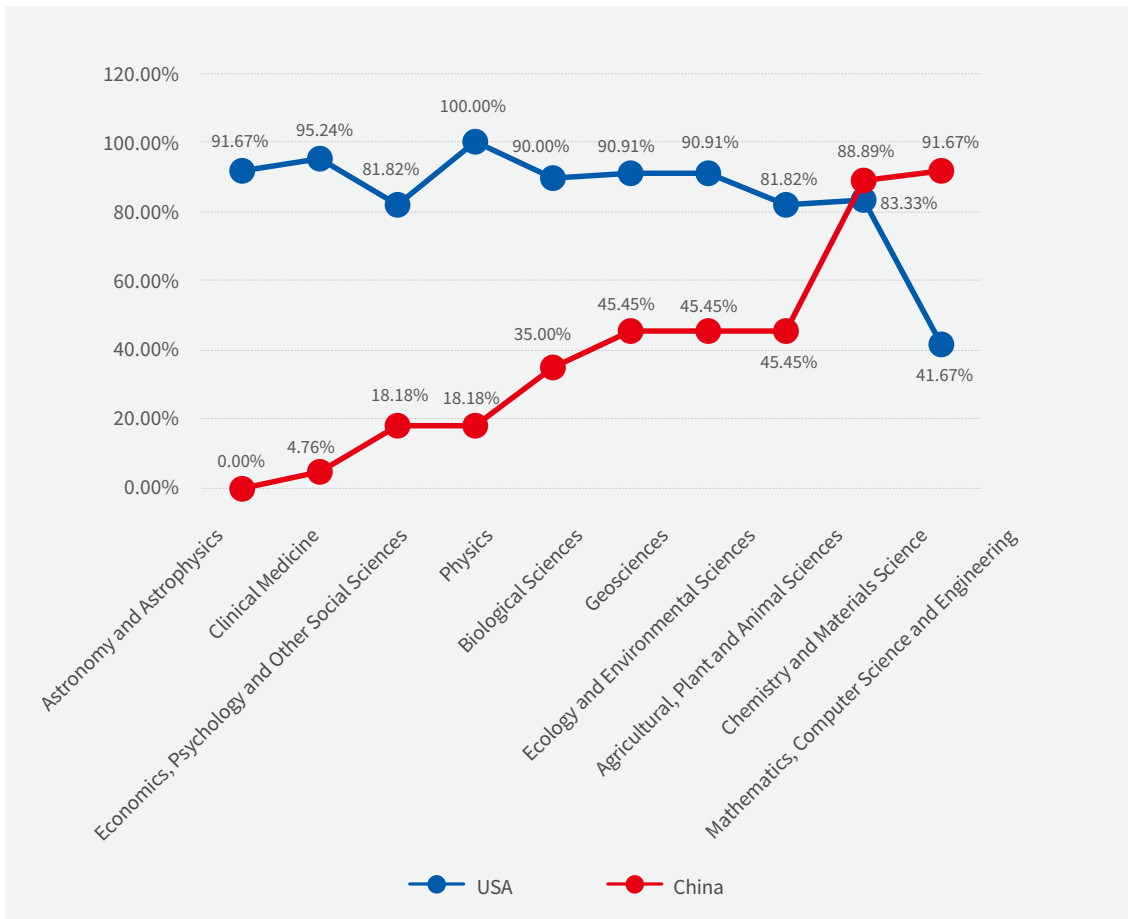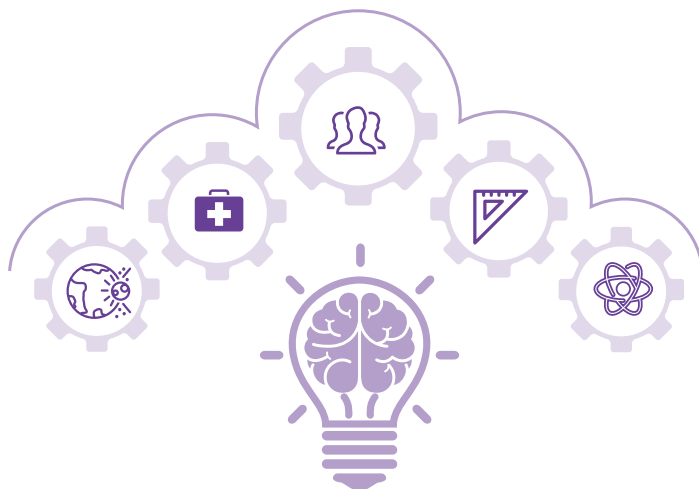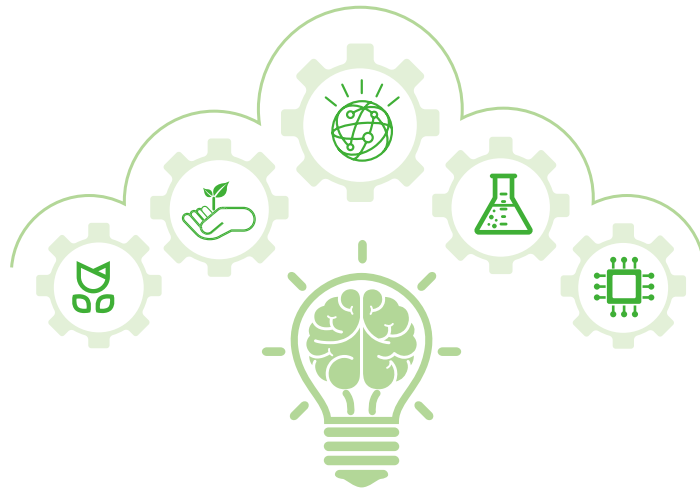
Fig 3. The ratios of the ranking Top three Research Fronts for China and the USA in 10 broad research areas with 138 Research Fronts (based on RLI$_{Ci}$)

The UK shows a sharp contrast to Germany in Economics, Psychology and Other Social Sciences. The UK scores 90.91% of the Research Fronts rank in Top three in this area, while Germany only has 9.09%.

Germany has 58.33% and 53.3% of the Research Fronts rank the Top three in Astronomy and Astrophysics and Physics; Germany has less than 50% Research Fronts rank the Top three in the other eight areas.
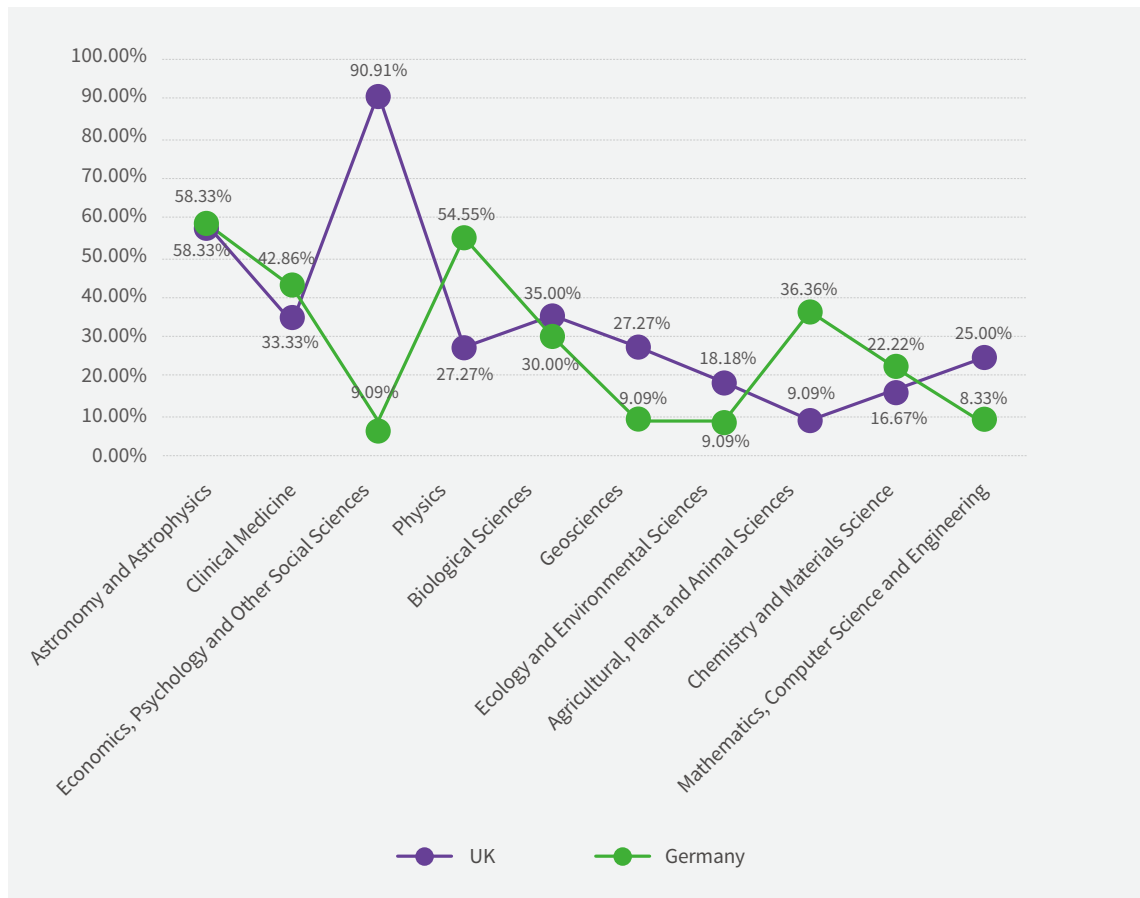

Fig 4. The ratios of the rankings among the Top 3 Research Fronts for the UK and Germany in 10 broad research areas with 138 Research Fronts (based on RLI$_{Ci}$)

3 Analysis of the Research Leadership Index (RLI$_{Cik}$) of countries in different areas

> With the score and ranking of the RLIC$_{ik}$, the Research Front activity and influence of various countries in specific areas are explored, and the particular strengths in national science and technological innovation are identified.

3.1 AGRICULTURAL, PLANT AND ANIMALSCIENCES: The USA is absolutely in the leading position, while China is ranked second

In Agricultural, Plant and Animal Sciences, the USA is the most active with a RLI$_{Cik}$ score 15.33, ranking 1st. China scores 8.07, ranking 2nd. Germany scores 6.39 for 3rd, followed by France and the UK. As seen in Table 5, the ranking of RFOI$_{Cik}$ and RFII$_{Cik}$ is the same as RLI$_{Cik}$ for the top 4 countries. The performances of the top 4 countries have strong consistency in three indicators. the UK's RFOI$_{Cik}$ and RFII$_{Cik}$ ranking are slightly different from its RLI$_{Cik}$ ranking.

Table 5. The score and rank of Top 5 countries based on RLI$_{Cik}$, RFOI$_{Cik}$ and RFII$_{Cik}$ in Agricultural, Plant and Animal Sciences

Indicators	Score					Rank				
	USA	China	Germany	France	UK	USA	China	Germany	France	UK
RLI$_{Cik}$	15.33	8.07	6.39	4.42	4.10	1	2	3	4	5
RFOI$_{Cik}$	7.80	4.91	3.26	2.29	2.05	1	2	3	4	6
RFII$_{Cik}$	7.54	3.16	3.12	2.14	2.04	1	2	3	4	5

3.2 ECOLOGY AND ENVIRONMENTAL SCIENCES: the the USA and China perform well, far beyond France, the UK and Germany

In the area of Ecology and Environmental Sciences, the USA scores 14.07 in RLI$_{Cik}$, ranking 1st, showing itself to be the most active. China scores 11.82, ranking 2nd. China's score in this area is close to that of the USA and far exceeds other countries. In third place is France, with a score of 4.53 and a significant distance from the top two. As can be seen from table 6, the ranking order of the top four countries – the USA, China, France and the UK -- remain the same in three indicators: RLI$_{Cik}$, RFOI$_{Cik}$ and RFII$_{Cik}$.

Table 6. The score and rank of Top 5 countries based on RLI$_{Cik}$, RFOI$_{Cik}$ and RFII$_{Cik}$ in Ecology and Environmental Sciences

Indicators	Score					Rank				
	USA	China	France	UK	Germany	USA	China	France	UK	Germany
RLI$_{Cik}$	14.07	11.82	4.53	4.24	3.84	1	2	3	4	5
RFOI$_{Cik}$	7.41	7.03	2.30	2.27	2.04	1	2	3	4	6
RFII$_{Cik}$	6.66	4.78	2.23	1.98	1.79	1	2	3	4	5

3.3 Geosciences: the USA is still the most active, China has jumped to second

In the area of Geosciences, the USA scores 21.49 in RLI$_{Cik}$, ranking 1st, far ahead of other countries. China scores 9.93, ranking 2nd, but still has a big gap compared with the USA. France, the UK and Canada score 7.43, 6.41 and 4.45, respectively, ranking 3rd, 4th and 5th. As can be seen from table 11, the Top four countries – the USA, China, France and the UK -- rank the same in three indicators RLI$_{Cik}$, RFOI$_{Cik}$ and RFII$_{Cik}$.

Table 7. The score and rank of Top 5 countries based on RLI$_{Cik}$, RFOI$_{Cik}$ and RFII$_{Cik}$ in Geosciences

Indicators	Score					Rank				
	USA	China	France	UK	Canada	USA	China	France	UK	Canada
RLI$_{Cik}$	21.49	9.93	7.43	6.41	4.45	1	2	3	4	5
RFOI$_{Cik}$	11.55	6.00	3.65	3.33	2.32	1	2	3	4	5
RFII$_{Cik}$	9.94	3.92	3.78	3.08	2.13	1	2	3	4	6

3.4 CLINICAL MEDICINE: The activity of the USA is preeminent, China is running faster

In the area of Clinical Medicine, the USA scores 41.44 in RLI$_{Cik}$, far ahead of other countries. Germany and the UK scores 17.96 and 14.60, respectively. China ranks 13th, and there is an obvious gap with other powers in this area.

The rank of Top 5 countries in RLI is identical to in RFOI$_{Cik}$ and RFII$_{Cik}$. China's ranking has changed slightly in three indicators. China ranks 13th on in RLI, while ranks 9th in RFOI$_{Cik}$, and 14 in RFII$_{Cik}$, indicating that China lacks important achievements of high impact in this area.

Table 8. The score and rank of Top 5 countries based on RLI$_{Cik}$, RFOI$_{Cik}$ and RFII$_{Cik}$ in Clinical Medicine

Indicators	Score						Rank					
	USA	Germany	UK	France	Italy	China	USA	Germany	UK	France	Italy	China
RLI$_{Cik}$	41.44	17.96	14.60	10.16	9.85	5.58	1	2	3	4	5	13
RFOI$_{Cik}$	21.38	8.57	7.46	5.04	5.09	3.37	1	2	3	5	4	9
RFII$_{Cik}$	20.05	9.39	7.14	5.12	4.76	2.21	1	2	3	4	5	14

3.5 BIOLOGICAL SCIENCES: The USA's activity is far ahead, while the respective performances of the UK, Germany and China are quite similar

In Biological Sciences, the USA ranks 1st, scoring 38.73 in RLI_{Cik}, nearly four times higher than the UK. The UK, Germany and China score very close to one another, at 10.58, 10.31 and 9.08, respectively, but there is a large gap between them and the USA. For the three indicators of China, $RFOI_{Cik}$ ranks 3rd, and $RFII_{Cik}$ ranks 5th, indicating that the performance of China in Output of Research Fronts is better than that in Citation influence.

Table 9. The score and rank of Top 5 countries based on RLI_{Cik}, $RFOI_{Cik}$ and $RFII_{Cik}$ in Biological Sciences

Indicators	Score					Rank				
	USA	UK	Germany	China	Italy	USA	UK	Germany	China	Italy
RLI_{Cik}	38.73	10.58	10.31	9.08	8.17	1	2	3	4	5
$RFOI_{Cik}$	21.00	5.63	5.17	5.57	4.18	1	2	4	3	5
$RFII_{Cik}$	17.73	4.95	5.14	3.50	3.99	1	3	2	5	4

3.6 CHEMISTRY AND MATERIALS SCIENCE: China and the USA are both active, China's RLI_{Cik} is slightly higher

In Chemistry and Materials Science, China's RLI_{Cik} score is 28.66, ranking 1st. The USA scores 22.37, ranking 2nd, but there is a small gap in activity between the USA and China. China scores four times higher than Germany. The UK, Japan and Germany score 5.94, 4.37 and 3.69 respectively, ranking 3rd to 5th. The rankings of the indicators RLI_{Cik}, $RFOI_{Cik}$ and $RFII_{Cik}$ for the Top 5 countries are exactly the same. China and the USA are consistently 1st and 2nd in three indicators, followed by Germany, the UK and South Korea.

Table 10. The score and rank of Top 5 countries based on RLI_{Cik}, $RFOI_{Cik}$ and $RFII_{Cik}$ in Chemistry and Materials Science

Indicators	Score					Rank				
	China	USA	Germany	UK	South Korea	China	USA	Germany	UK	South Korea
RLI_{Cik}	28.66	22.37	5.94	4.37	3.69	1	2	3	4	5
$RFOI_{Cik}$	16.52	11.54	3.32	2.19	2.05	1	2	3	4	5
$RFII_{Cik}$	12.14	10.83	2.62	2.18	1.65	1	2	3	4	5

3.7 PHYSICS: The USA gain competitive advantages in the activity, while Germany, China and the UK show outstanding performances in certain fronts

In the area of Physics, the USA demonstrates the highest degree of activity, with a RLI_{Cik} of 17.55, two times as that of Germany. Germany and China score 8.05 and 6.12 respectively, while the UK and Italy rank 4th and 5th with respective scores of 5.71 and 4.29.

Table 1.1 The score and rank of Top 5 countries based on RLI_{Cik}, $RFOI_{Cik}$ and $RFII_{Cik}$ in Physics

Indicators	Score					Rank				
	USA	Germany	China	UK	Italy	USA	Germany	China	UK	Italy
RLI_{Cik}	17.55	8.05	6.12	5.71	4.29	1	2	3	4	5
$RFOI_{Cik}$	9.73	4.32	3.73	3.00	2.35	1	2	3	4	5
$RFII_{Cik}$	7.81	3.73	2.39	2.71	1.94	1	2	4	3	6

3.8 ASTRONOMY AND ASTROPHYSICS: the USA, the UK, Germany, France and Spain are the top five, and China's current activity is not satisfactory

In the area of Astronomy and Astrophysics, the USA ranks 1st, with a RLI_{Cik} score 26.54. The UK ranks 2nd with 17.86. Germany ranks 3rd with 15.48, followed by France (10.43) and Spain (10.01). Although the USA has the highest RLI_{Cik}, the UK, Germany, and France are also outstanding in this area. China, ranking 19th with a score of 4.22, confronts a significant gap in activity level with other countries.

Table 12. The score and rank of Top 5 countries based on RLI_{Cik}, $RFOI_{Cik}$ and $RFII_{Cik}$ in Astronomy and Astrophysics

Indicators	Score						Rank					
	USA	UK	Germany	France	Spain	China	USA	UK	Germany	France	Spain	China
RLI_{Cik}	26.54	17.86	15.48	10.43	10.01	4.22	1	2	3	4	5	19
$RFOI_{Cik}$	14.27	8.99	8.06	5.09	4.61	2.21	1	2	3	4	6	17
$RFII_{Cik}$	12.27	8.86	7.42	5.34	5.40	2.01	1	2	3	5	4	21

3.9 MATHEMATICS, COMPUTER SCIENCE AND ENGINEERING: China's Research Fronts are super active, as the USA follows closely

In the area of Mathematics, Computer Science and Engineering, China has the most active performance. China ranks 1st with an RLI_{Cik} score of 31.52 while the USA posts a score of 5.15 and ranks 2nd. The UK, Australia and Italy score 3.17, 3.12 and 2.83 respectively, ranking 3rd, 4th, and 5th.

Table 13. The score and rank of Top 5 countries based on RLI$_{Cik}$, RFOI$_{Cik}$ and RFII$_{Cik}$ in Mathematics, Computer Science and Engineering

Indicators	Score					Rank				
	China	USA	UK	Australia	Italy	China	USA	UK	Australia	Italy
RLI$_{Cik}$	31.52	5.15	3.17	3.12	2.83	1	2	3	4	5
RFOI$_{Cik}$	17.85	2.81	1.84	1.77	1.54	1	2	3	4	5
RFII$_{Cik}$	13.67	2.34	1.33	1.35	1.28	1	2	4	3	5

3.10 ECONOMICS, PSYCHOLOGY AND OTHER SOCIAL SCIENCES: The The USA has an obvious advantage, and China follows closely

In this area of Economics, Psychology and Other Social Sciences, the USA has the highest level of activity with an RLI$_{Cik}$ score of 24.73, ranking 1st. The UK and Australia score 7.59 and 4.28, respectively, ranking 2nd and 3rd. The top three countries' rankings are the same in terms of the three indicators RLI$_{Cik}$, RFOI$_{Cik}$ and RFII$_{Cik}$. The RLI$_{Cik}$ of China 3.40, ranking 4th. But China's ranking in influence degree (RFII$_{Cik}$) is lower than that of Output Share (RFOI$_{Cik}$).

Table 14. The score and rank of Top 5 countries based on RLI$_{Cik}$, RFOI$_{Cik}$ and RFII$_{Cik}$ in Economics, Psychology and Other Social Sciences

Indicators	Score					Rank				
	USA	UK	Australia	China	Belgium	USA	UK	Australia	China	Belgium
RLI$_{Cik}$	24.73	7.59	4.28	3.40	2.60	1	2	3	4	5
RFOI$_{Cik}$	12.39	4.26	2.48	2.16	1.32	1	2	3	4	6
RFII$_{Cik}$	12.34	3.33	1.80	1.24	1.27	1	2	3	6	5