2019 Research Fronts: Active Fields, Leading Countries

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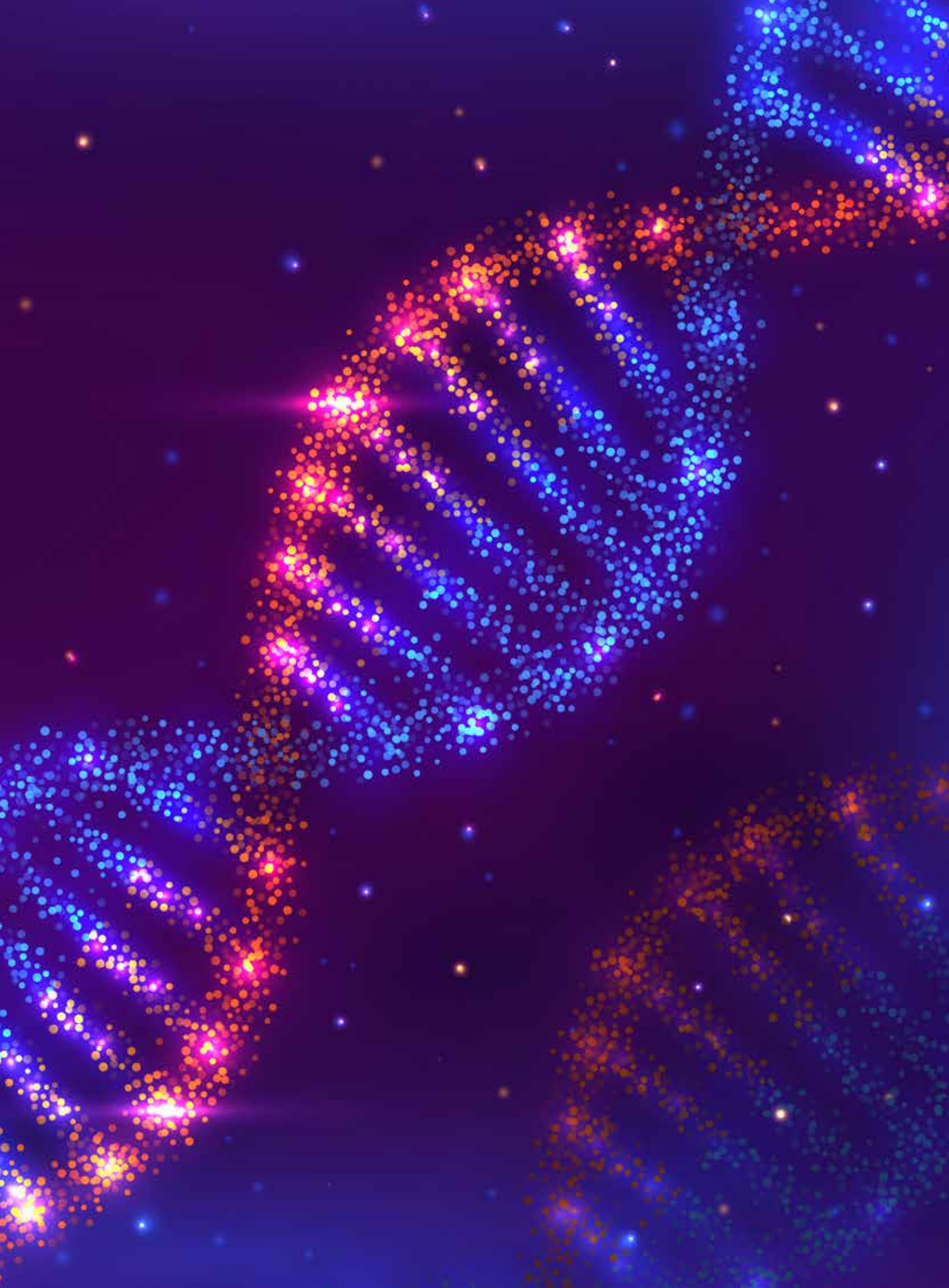


Science and technology are universal and epochal, and the development of science and technology must be viewed from a global perspective. At present, major breakthroughs and accelerated applications of technological innovation have been instrumental in reshaping the global economic structure and transforming the arena of industrial and economic competition. The "Research Fronts 2019" report is a prequel to another survey, "Research Fronts 2019: Active Fields, Leading Countries," having selected and discussed 100 hot fronts and 37 emerging fronts in 10 broad research areas. Based on the findings of "Research Fronts 2019," the second report 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.

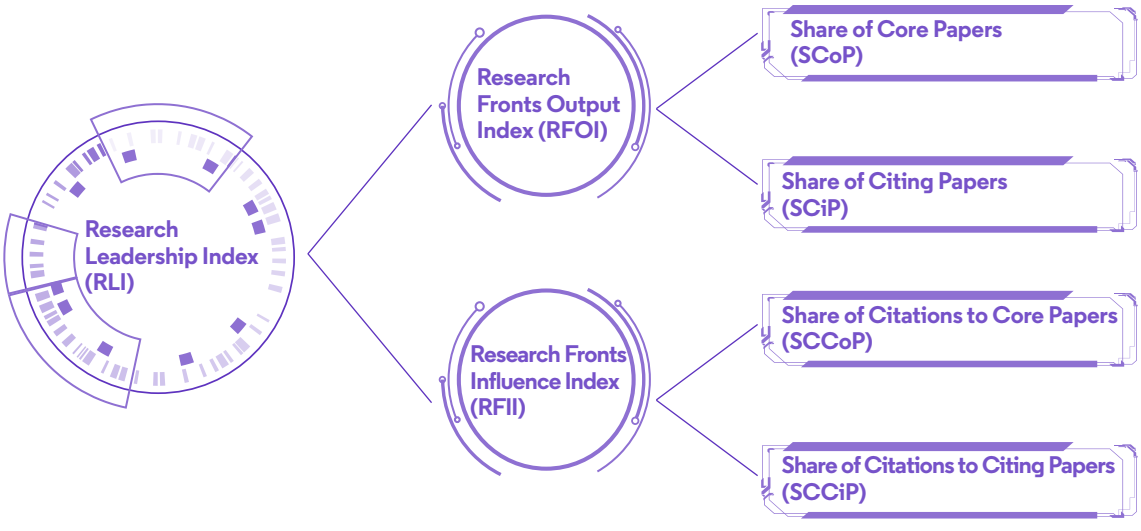
100 hot Research Fronts
37 emerging Research Fronts
in 10 broad research areas

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 degree of activity in Research Fronts. Since a Research Front itself is composed of a group of highly cited core papers along with subsequent papers that cite the core literature, the design of the Research Leadership Index takes into account the numbers of the core papers and citing papers, as well as their respective citations. These calculations underlie two indicators: Output Share and Citation Share. The logical model of Research Leadership Index (RLI) is shown in Figure 1.

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



The objects measured by the Research Leadership Index can be countries, cities, institutions, laboratories, teams, and individual scientists. Each object can be measured at three levels: Research Front level, area level, and a level within the context of 10 broad research areas.

1.2 Research Leadership Index of country (RLI_C)

This report calculated the Research Leadership Index of main countries at the Research Front level, area level, and the level of all 10 broad research areas. Based on that, we determined the degree of activity in innovation and its pattern within the main countries as reflected in Research Fronts, and revealed the sources of research vitality in various countries. The methods for 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 degree of activity of a country as reflected in Research Fronts, including two aspects of the output and citation influence of papers in the fronts. The equation for Research Leadership Index of Country in a Research Front (RLI_{Cij}) is:

$$\mathrm{RLI}_{Cij} = \mathrm{RFOI}_{Cij} + \mathrm{RFII}_{Cij} = \frac{CoP_{ij}}{CoP_j} + \frac{CiP_{ij}}{CiP_j} + \frac{CoC_{ij}}{CoC_j} + \frac{CiC_{ij}}{CiC_j}$$

$RFOI_{Cij}$ is Research Fronts Output Index of a country, $RFII_{Cij}$ is Research Fronts Influence Index of a country, j represents the Research Front, i represents each country.

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

The 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. $RFOI_{Cij}$ equal to the sum of the two indicators $SCoP_{Cij}$ and $SCiP_{Cij}$

$$\mathrm{RFOI}_{Cij} = \mathrm{SCoP}_{Cij} + \mathrm{SCiP}_{Cij} = \frac{CoP_{ij}}{CoP_j} + \frac{CiP_{ij}}{CiP_j}$$

Country's Share of Core Papers in a Research Front ($SCoP_{Cij}$) indicates the percentage of CoP_{ij} in CoP_j.

$$\mathrm{SCoP}_{Cij} = \frac{CoP_{ij}}{CoP_j}$$

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

Country's Share of Citing Papers in a Research Front ($SCiP_{Cij}$) indicates the percentage of CiP_{ij} in CiP_j.

$$\mathrm{SCiP}_{Cij} = \frac{CiP_{ij}}{CiP_j}$$

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) a country contributed in a Research Front. $RFII_{Cij}$ equals the sum of the two indicators $SCCoP_{Cij}$ and $SCCiP_{Cij}$.

$$\mathrm{RFII}_{Cij} = SCCoP_{Cij} + SCCiP_{Cij} = \frac{CoC_{ij}}{CoC_j} + \frac{CiC_{ij}}{CiC_j}$$

Country's Share of Core Paper Citation for a Research Front ($SCCoP_{Cij}$) indicates the percentage of CoC_{ij} in CoC_j.

$$\mathrm{SCCoP}_{Cij} = \frac{CoC_{ij}}{CoC_j}$$

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.

Country's Share of Citation to Citing Paper in a Research Front ($SCCiP_{Cij}$) indicates the percentage of CiC_{ij} in CiC_j.

$$\mathrm{SCCiP}_{Cij} = \frac{CiC_{ij}}{CiC_j}$$

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

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 for RLI_{Cik} is as follow:

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

RLI_{Cik} equal to 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 and citing) contributed by a country to an area composed of n Research Fronts. $RFOI_{Cik}$ is equal to the sum of the two indicators $SCoP_{Cik}$ and $SCiP_{Cik}$.

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

The formula for a country's Share of Core Paper in an area ($SCoP_{Cik}$) is as follows:

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

The formula for a country's Share of Citing Paper in an area ($SCiP_{Cik}$) is below:

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

(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 and citing) contributed by a country to an area composed of n Research Fronts. $RFII_{Cik}$ equal to the sum of the two indicators $SCCoP_{Cik}$ and $SCCiP_{Cik}$.

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

The formula for a country's Share of Citations to Core Papers in an area ($SCCoP_{Cik}$) is as follows:

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

The formula for a country's Share of Citations to Citing Papers in an area ($CiCS_{Cik}$) is below:

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

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}) represents the scores of RLI_{Cik} of the 10 broad areas added together. The index is a comprehensive evaluation index to measure the degree of activity of a country based on its contribution to 10 broad research areas composed of 137 Research Fronts.

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

RLI_{Ci} is equal to the sum of the two indicators $RFOI_{Ci}$ and $RFII_{Ci}$。

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

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 and citing) contributed by a country to 10 broad research areas composed of 137 Research Fronts. $RFOI_{Ci}$ is equal to the sum of the two indicators $SCoP_{Ci}$ and $SCiP_{Ci}$.

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

The formula for a country's Share of Core Papers in 10 broad research areas ($SCoP_{Ci}$) is as follows:

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

The formula for a country's Share of Citing Papers in 10 broad research areas ($SCiP_{Ci}$) is as follows:

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

(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 citation of papers (core and citing) contributed by a country to 10 broad research areas composed of 137 Research Fronts. $RFII_{Ci}$ is equal to the sum of the two indicators $SCCoP_{Ci}$ and $SCCiP_{Ci}$.

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

The formula for a country's Share of Citations to Core Papers in 10 broad research areas ($SCCoP_{Ci}$) is as follows:

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

The formula for a country's Share of Citations to Citing Papers in 10 broad research areas ($SCCiP_{Ci}$) is:

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

2 Analysis of the RLI_{Ci} of Top countries

> We measured the RLI_{ci} of main countries for overall performance in 10 broad research areas comprising 137 Research Fronts, and ranked the top countries. The following highlights are noted.

2.1 The USA remains the most active, while the gap in RLI_{Ci} between China and the USA has narrowed

For 10 broad research areas comprising 137 Research Fronts, the USA is the most active, with an RLI_{ci} score of 204.89, ranking 1st. China ranks 2nd with a score of 139.68. The UK and Germany score 80.85 and 67.52, respectively, ranking 3rd and 4th.

The RLI_{ci} scores for France, Italy, Canada, Australia, the Netherlands, and Japan register between 50 and 30, ranking those nations from 5th to 10th, with Japan (at 33.15) rounding out the top 10 by this measure.

1	2	3	4
The USA:	China:	The UK:	Germany:
204.89	**139.68**	**80.85**	**67.52**

Fig 2. **Research Leadership Index (RLI_{Ci}) of Top 20 Countries in 10 broad research areas with 137 Research Fronts**

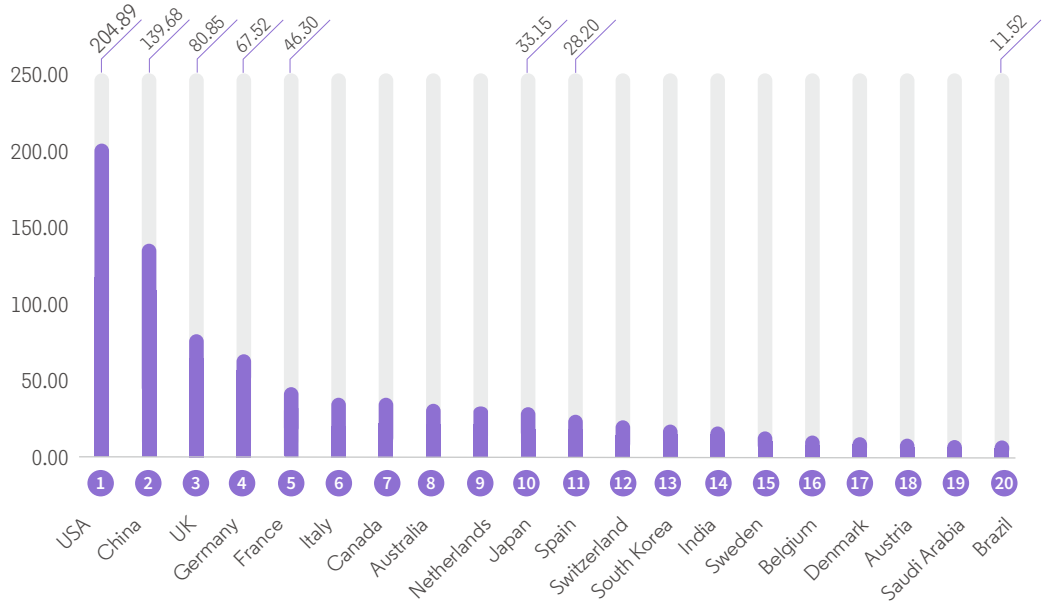


Table 1 shows that the rank order for the three indicators RLI_{Ci}, $RFOI_{Ci}$ and $RFII_{Ci}$ for the top five countries is the same. For the remaining countries, scores on the three indicators do not differ widely, although precise calculation ranks the nations from 6th to 20th.

Table 1. **The Research Leadership Index (RLI_{Ci}) of Top 20 Countries in 10 broad research areas with 137 Research Fronts**

	RLI_{Ci}		$RFOI_{Ci}$		$RFII_{Ci}$	
	Score	Rank	Score	Score	Rank	Score
USA	204.89	1	107.35	1	97.54	1
China	139.68	2	81.70	2	57.98	2
UK	80.85	3	42.01	3	38.83	3
Germany	67.52	4	35.06	4	32.46	4
France	46.30	5	23.52	5	22.79	5
Italy	39.42	6	21.50	6	17.92	7
Canada	39.25	7	18.98	7	20.27	6
Australia	35.27	8	17.48	9	17.79	8
Netherlands	33.80	9	16.27	10	17.53	9
Japan	33.15	10	17.72	8	15.44	10
Spain	28.20	11	14.81	11	13.39	11
Switzerland	24.81	12	12.33	12	12.48	12

	RLI_{Ci}		$RFOI_{Ci}$		$RFII_{Ci}$	
	Score	Rank	Score	Score	Rank	Score
South Korea	21.75	13	10.75	14	11.00	13
India	20.74	14	10.90	13	9.84	14
Sweden	17.54	15	8.66	15	8.87	15
Belgium	14.83	16	7.44	16	7.39	17
Denmark	13.91	17	6.04	18	7.86	16
Austria	12.75	18	5.92	19	6.83	18
Saudi Arabia	12.01	19	6.36	17	5.65	20
Brazil	11.52	20	5.76	20	5.76	19

Table 2 compares the Research Leadership Index (RLI_{Ci}) of the top five countries in 2017, 2018, and 2019, and the proportion relative to the USA. The top five countries in the three years are completely the same. The USA scores 281.11, 227.39 and 204.89 respectively in the three years, maintaining 1st place. China ranks 2nd with 118.84, 118.38, and 139.68 points in three years, rising steadily, and the gap between China and the USA in RLI_{Ci} is gradually narrowing. The analysis also calculates the ratio of other countries to the USA at 100% per year. The ratio of China to the USA is 42.28%, 52.06%, and 68.18% for the three years. Thus, the proportion of China to the USA is increasing year by year, and the progress is obvious. Meanwhile, the UK, Germany, and France rank 3rd to 5th in 2017 to 2019, but the proportion changes slightly compared with the USA.

Table 2. Research Leadership Index (RLI_{Ci}) for Top 20 Countries in 10 broad research areas with 137 Research Fronts, for each of three years, 2017 to 2019

Country	RLI_{Ci}					
	2017 Score	2017 %	2018 Score	2018%	2019 Score	2019 %
USA	281.11	100.00%	227.39	100.00%	204.89	100.00%
China	118.84	42.28%	118.38	52.06%	139.68	68.18%
UK	96.9	34.47%	78.62	34.57%	80.85	39.46%
Germany	90.98	32.36%	75.12	33.04%	67.52	32.95%
France	60.08	21.37%	51.2	22.52%	46.30	22.60%

2.2 The USA shows obvious strength in leading seven areas, while China has outstanding performance in three areas, but lags in two

For the 10 broad research areas, the USA's RLI_{Ci} scores are 1st in seven of the main areas (and by a notably wide margin), except for three areas: "Chemistry and materials science", "Mathematics, computer science and engineering," and "Ecology and environmental science." In all three of the latter, China ranks 1st. China ranks 2nd in five areas: "Agricultural, plant and animal sciences", "Geosciences," "Biological science," "Physics," and "Economics, psychology and other social sciences," with outstanding performance. China, however, ranks 9th and 11th in the areas of "Clinical medicine" and "Astronomy and astrophysics," showing that the nation still has ground to gain in those two broad specialties.

Table 3. The score and rank of RLI_{Ci} and RLI_{Cik} of Top20 Countries

	10 broad research areas		Agricultural, plant and animal sciences		Ecology and environmental science		Geosciences		Clinical medicine		Biological science		Chemistry and materials science		Physics		Astronomy and astrophysics.		Mathematics, computer science and engineering		Economics, psychology and other social sciences	
Countries	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
USA	204.89	1	13.02	1	11.19	2	22.13	1	41.31	1	28.28	1	13.03	2	18.68	1	30.98	1	10.75	2	15.53	1
China	139.68	2	9.43	2	14.23	1	10.92	2	7.11	9	12.36	2	26.53	1	9.43	2	6.91	11	33.55	1	9.23	2
UK	80.85	3	5.53	5	2.78	7	4.54	5	21.38	2	9.78	3	4.02	5	5.24	4	16.28	3	4.99	4	6.30	3
Germany	67.52	4	5.65	3	3.28	4	2.16	8	14.03	3	4.84	5	4.44	3	7.96	3	17.13	2	1.91	10	6.11	4
France	46.30	5	5.58	4	2.69	8	5.06	4	10.08	5	4.19	7	1.07	10	2.74	7	11.12	5	1.78	12	1.98	9
Italy	39.42	6	3.15	7	2.14	11	1.09	14	10.01	6	5.27	4	0.88	14	3.54	6	10.43	6	1.03	18	1.87	11
Canada	39.25	7	2.71	8	2.06	13	6.15	3	10.15	4	1.80	16	1.03	12	2.67	8	8.35	9	2.21	9	2.13	8
Australia	35.27	8	3.53	6	3.56	3	3.07	6	8.50	7	2.08	13	0.96	13	0.88	18	7.80	10	1.64	13	3.25	7
Netherlands	33.80	9	1.49	19	2.42	9	0.60	19	6.60	10	4.10	8	1.09	9	2.15	12	9.50	7	0.26	30	5.58	5
Japan	33.15	10	1.73	15	1.65	16	2.98	7	4.21	11	2.29	11	2.33	6	2.47	9	11.25	4	2.92	7	1.32	15
Spain	28.20	11	1.86	14	2.10	12	0.84	17	7.20	8	2.16	12	0.64	16	2.40	10	8.67	8	0.54	25	1.80	13
Switzerland	24.81	12	1.63	16	1.76	15	0.85	16	3.58	15	4.33	6	1.07	11	3.62	5	6.40	12	0.29	29	1.29	17
South Korea	21.75	13	2.16	12	2.29	10	0.40	25	3.30	16	1.55	20	1.29	8	1.84	13	4.67	14	3.34	6	0.90	20
India	20.74	14	1.97	13	2.79	6	1.47	10	0.37	41	3.82	9	1.32	7	2.15	11	4.26	17	1.35	15	1.25	18
Sweden	17.54	15	2.54	9	1.01	23	1.65	9	4.06	13	1.81	15	0.43	17	0.85	21	3.80	20	0.59	23	0.79	22
Belgium	14.83	16	1.56	17	1.47	17	0.32	29	4.18	12	0.72	25	0.21	22	0.45	26	4.31	16	0.12	41	1.48	14
Denmark	13.91	17	1.08	22	1.42	18	0.79	18	3.91	14	1.28	21	0.15	26	1.48	15	2.68	23	0.45	26	0.67	23
Austria	12.75	18	0.63	30	1.06	22	1.10	13	2.47	18	1.13	23	0.36	20	0.50	25	1.82	26	0.20	33	3.48	6
Saudi Arabia	12.01	19	1.08	21	2.85	5	0.12	47	0.14	49	0.60	27	0.80	15	0.21	38	0.02	62	6.00	3	0.21	32
Brazil	11.52	20	1.39	20	0.62	26	0.17	40	1.76	23	2.30	10	0.08	32	0.68	23	3.53	21	0.13	39	0.87	21

Among the 100 hot Research Fronts and 37 emerging Research Fronts in 10 broad research areas, the USA ranks 1st in 80, accounting for 58.39% of the137 Research Fronts. China earns the top spot in 3 fronts, or 24.09%. The UK is tops in seven Research Fronts, while Germany and France can each claim the top ranking in one front (Table 4).

Of the 10 broad research areas, "Mathematics, computer science and engineering," and "Chemistry and materials science" are the two most advanced areas for China, with the country ranking 1st in more than 50% of the Research Fronts within each of those two broad groupings. In fact, in the area of "Mathematics, computer science and engineering," China can boast 1st place in 62.50% of the constituent Research Fronts. In "Ecology and environmental science," China ranks 1st in four Research Fronts, a showing equal to that of the USA. Solid performance by China can also be seen in "Physics" (1st in three fronts), "Geoscience," "Biological science," and "Economics, psychology and other social sciences" (each with China 1st in two fronts). In two areas – "Agricultural, plant and animal sciences" and "Clinical medicine" – China registers 1st in a Research Front. By contrast, China does not rank 1st in any of the fronts within "Astronomy and astrophysics."

Compared with China, the USA accounts for 1st-place rankings in only 12.50% of the Research Fronts in "Mathematics, computer science and engineering," and in only 26.67% of those in "Chemistry and materials science." These two areas, meanwhile, are highly active in terms of Chinese representation. Due to China's progress in "Ecology and environmental sciences," the USA ranks 1st in four Research Fronts in this area, which is relatively less than its showing in other areas.

In addition to the above three fields, the USA claims 1st-place performance in more than 60% of the Research Fronts in each of these seven areas: "Agricultural, plant and animal sciences," "Geoscience," "Clinical medicine," "Biological science," "Physics," "Astronomy and astrophysics," and "Economics, psychology and other social sciences" – the best showing among all countries.

The UK, Germany, and France are all in the top five positions in the 10 areas, showing significant strength.

The USA ranks 1st in
80 Research Fronts

China ranks 1st in
33 Research Fronts

The UK ranks 1st in
7 Research Fronts

Germany ranks 1st in
1 Research Front

France ranks 1st in
1 Research Front

Table 4. The numbers and ratios of the Research Fronts in which the respective Top 5 countries rank first, out of 137 fronts in 10 broad research areas (based on RLI_{Ci})

Areas	Numbers of RFs	Numbers of ranking 1st RFs					Ratios				
		USA	China	UK	Germany	France	USA	China	UK	Germany	France
10 broad research areas total	137	80	33	7	1	1	58.39%	24.09%	5.11%	0.73%	0.73%
Agricultural, plant and animal sciences	11	7	1	1	0	0	63.64%	9.09%	9.09%	0.00%	0.00%
Ecology and environmental sciences	11	4	4	0	0	0	36.36%	36.36%	0.00%	0.00%	0.00%

Areas	Numbers of RFs	Numbers of ranking 1st RFs					Ratios				
		USA	China	UK	Germany	France	USA	China	UK	Germany	France
Geosciences	11	8	2	0	0	0	72.73%	18.18%	0.00%	0.00%	0.00%
Clinical medicine	21	16	1	3	0	0	76.19%	4.76%	14.29%	0.00%	0.00%
Biological sciences	16	12	2	1	0	0	75.00%	12.50%	6.25%	0.00%	0.00%
Chemistry and materials science	15	4	8	1	1	0	26.67%	53.33%	6.67%	6.67%	0.00%
Physics	12	8	3	0	0	0	66.67%	25.00%	0.00%	0.00%	0.00%
Astronomy and astrophysics	13	11	0	1	0	1	84.62%	0.00%	7.69%	0.00%	7.69%
Mathematics, computer science and engineering	16	2	10	0	0	0	12.50%	62.50%	0.00%	0.00%	0.00%
Economics, psychology and other social sciences	12	8	2	0	0	0	66.67%	16.67%	0.00%	0.00%	0.00%

Among nations ranking among the top three performers in these Research Fronts (Table 5), the USA earns that distinction in 115 fronts, or 83.94%, China in 63 Research Fronts（45.99%), the UK in 46, and Germany in 43. The latter two countries – although their percentages of top-three placements are lower than those of the USA and China – can each boast the achievement in nearly one-third of the total number of Research Fronts.

Table 5. The numbers and ratios of nations ranking among the top three performers in Research Fronts, among the Top 5 countries in 10 broad research areas with 137 Research Fronts (based on RLI_{Ci})

Areas	Numbers of RFs	Numbers of ranking Top three RFs					Ratios				
		USA	China	UK	Germany	France	USA	China	UK	Germany	France
10 broad research areas total	137	115	63	46	43	18	83.94%	45.99%	33.58%	31.39%	13.14%
Agricultural, plant and animal sciences	11	8	6	3	3	4	72.73%	54.55%	27.27%	27.27%	36.36%
Ecology and environmental sciences	11	7	8	2	2	2	63.64%	72.73%	18.18%	18.18%	18.18%
Geosciences	11	10	5	2	0	3	90.91%	45.45%	18.18%	0.00%	27.27%
Clinical medicine	21	20	2	12	7	3	95.24%	9.52%	57.14%	33.33%	14.29%
Biological sciences	16	15	6	8	5	1	93.75%	37.50%	50.00%	31.25%	6.25%
Chemistry and materials science	15	11	14	3	6	1	73.33%	93.33%	20.00%	40.00%	6.67%
Physics	12	11	4	2	6	0	91.67%	33.33%	16.67%	50.00%	0.00%
Astronomy and astrophysics	13	13	0	6	7	4	100.00%	0.00%	46.15%	53.85%	30.77%

Areas	Numbers of RFs	Numbers of ranking Top three RFs					Ratios				
		USA	China	UK	Germany	France	USA	China	UK	Germany	France
Mathematics, computer science and engineering	16	10	14	3	2	0	62.50%	87.50%	18.75%	12.50%	0.00%
Economics, psychology and other social sciences	12	10	4	5	5	0	83.33%	33.33%	41.67%	41.67%	0.00%

In the area of "Astronomy and astrophysics," the USA ranks among the top three performers in 100% of the pertinent Research Fronts. The nation also makes the top three in more than 90% of the respective Research Fronts associated with four areas: "Physics," "Clinical medicine," "Biological science," and "Geosciences." This notably superior performance also carried over into "Agricultural, plant and animal sciences" and "Economics, psychology and other social sciences" – both areas in which the USA ranked among the top three in 70% to 80% of the Research Fronts. Only in the areas of "Chemistry and materials science," "Mathematics, computer science and engineering," and "Ecology and environmental science" did the USA's proportion of top-three placements score lower than that of China.

In fact, comparatively speaking, China is the most active in those three areas, accounting for 93.33% of top-three placements in Research Fronts pertaining to "Chemistry and materials science," 87.50% in "Mathematics, computer science and engineering," and 72.73% in "Ecology and environmental science."

In "Agricultural, plant and animal sciences", China posts an impressive performance, earning top-three spots in 54.55% of the Research Fronts.

In "Geosciences," China registers among the top three in 45.45% of the Research Fronts. In these two areas China is in 2nd position, behind the USA.

The UK ranks in the top three in 57.14% and 50.00% of Research Fronts in "Clinical medicine" and "Biological science". Germany ranks in the top three in 53.85% and 50.00% of Research Fronts in "Astronomy and astrophysics" and "Physics". While not quite as prominent as the USA, the performance of the two nations is notable in these areas.

China, meanwhile, places among the top three in 9.52% of the Research Fronts in "Clinical medicine," although not attaining that distinction in any of the fronts in "Astronomy and astrophysics."

Fig 3. **The ratios of the ranking Top three Research Fronts for China and USA in 10 broad research areas with 137 Research Fronts (based on RLI_{Ci})**

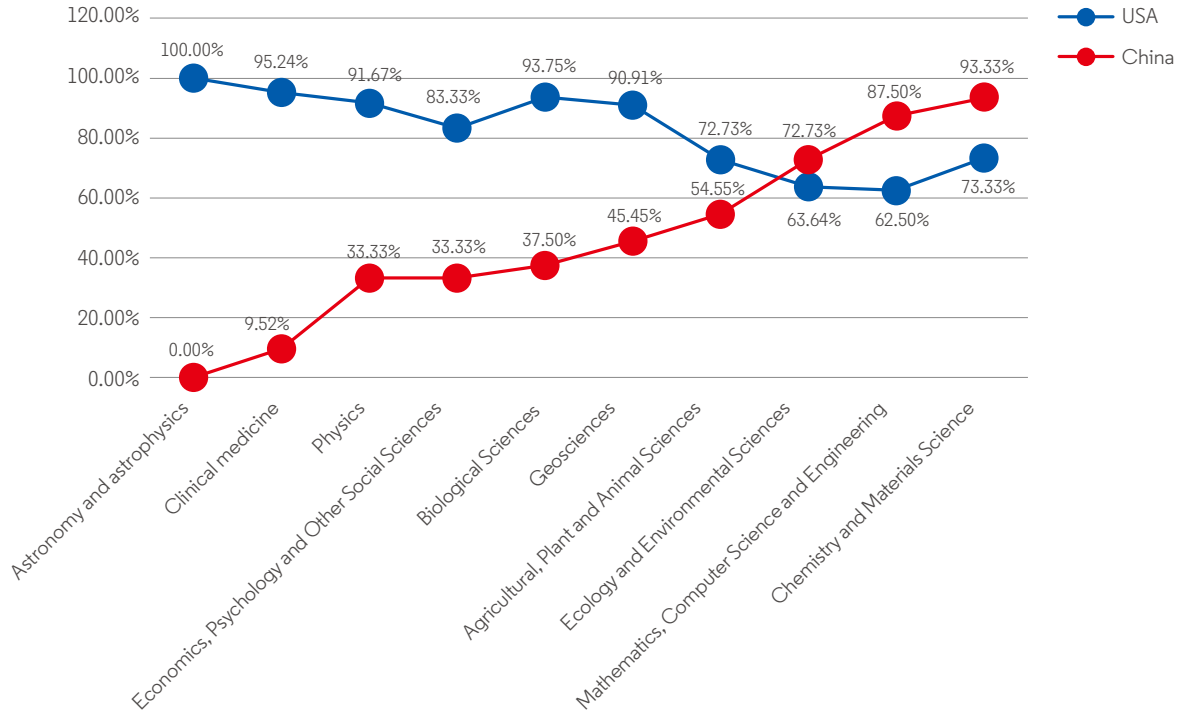
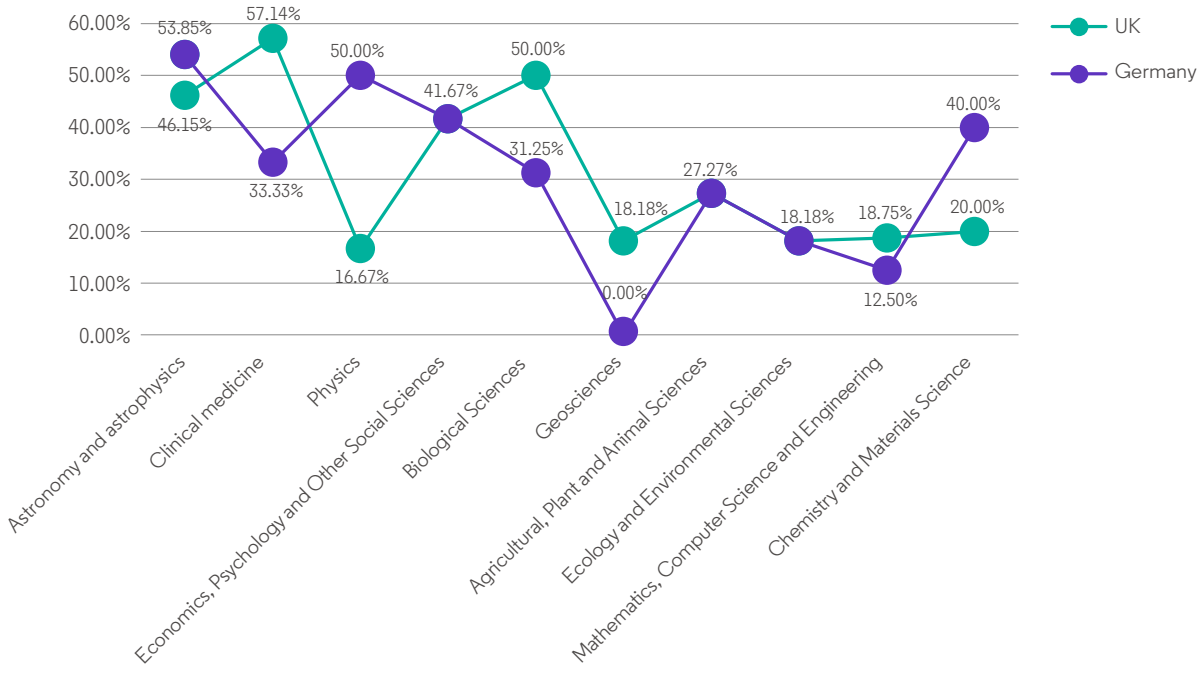


Fig 4. **The ratios of Research Fronts in which the UK and Germany rank among the top three performers, in 10 broad research areas comprising 137 Research Fronts (based on RLI_{Ci})**



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

"This section highlights the scores and rankings obtained via the RLI_{Cik} measurement, exploring the Research Front activity and influence of various countries in specific areas, and analyzing the respective sources of national vitality in scientific and technical innovation."

3.1 AGRICULTURAL, PLANT AND ANIMAL SCIENCES: The USA is absolutely in the leading position; China is 2nd; Germany, France and UK are the 3rd, 4th and 5th

In the area of "Agricultural, plant and animal sciences," the USA is the most active according to its RLI_{Cik} score of 13.02, ranking 1st. China scores 9.43, ranking 2nd. Germany scores 5.65 for 3rd place, followed by France and the UK. As can be seen from Table 6, the ranking according to $RFOI_{Cik}$ and $RFII_{Cik}$ is the same as RLI_{Cik} for the USA and China. By contrast, the rankings for UK, Germany, and France vary slightly according to the different indicators.

1 The USA: **13.02**

2 China: **9.43**

3 Germany: **5.65**

Table 6. The score and rank of Top 5 countries based on RLI_{Cik}, $RFOI_{Cik}$ and $RFII_{Cik}$ in the area of "Agricultural, plant and animal sciences"

Indicators	Score					Rank				
	USA	China	Germany	France	UK	USA	China	Germany	France	UK
RLI_{Cik}	13.02	9.43	5.65	5.58	5.53	1	2	3	4	5
$RFOI_{Cik}$	6.33	5.23	2.87	2.72	2.98	1	2	4	5	3
$RFII_{Cik}$	6.70	4.20	2.78	2.87	2.55	1	2	4	3	5

3.2 ECOLOGY AND ENVIRONMENTAL SCIENCES: China is in the leading position; The USA is 2nd; with Australia, Germany, and Saudi Arabia ranking 3rd, 4th and 5th

In the area of "Ecology and environmental sciences" (Table 7), China scores 14.23 in RLI_{Cik}, ranking 1st, demonstrating the most activity. The USA scores 11.19, ranking 2nd. In third place is Australia, with its score of 3.56 significantly lower than the top two. Germany and Saudi Arabia rank 4th and 5th. The rank order of the top two countries, China and the USA, remains the same for all three indicators. RLI_{Cik}, $RFOI_{Cik}$ and $RFII_{Cik}$.

1 China: **14.23**

2 The USA: **11.19**

3 Australia: **3.56**

Table 7. The score and rank of Top 5 countries based on RLI_{Cik}, $RFOI_{Cik}$ and $RFII_{Cik}$ in the area of "Ecology and environmental sciences"

Indicators	Score					Rank				
	China	USA	Australia	Germany	Saudi Arabia	China	USA	Australia	Germany	Saudi Arabia
RLI_{Cik}	14.23	11.19	3.56	3.28	2.85	1	2	3	4	5
$RFOI_{Cik}$	8.39	5.60	1.92	1.64	1.30	1	2	3	4	8
$RFII_{Cik}$	5.84	5.59	1.64	1.64	1.55	1	2	4	3	5

3.3 Geosciences: The USA is the most active, China is 2nd still faces a large in with gap with the USA; Canada, France and UK are 3rd, 4th, and 5th

In the area of "Geosciences", the USA scores 22.13 in RLI_{Cik}, ranking 1st, far ahead of other countries. China scores 10.92, ranking 2nd, but still faces a large in with gap with the USA. Canada, France, and the UK score 6.15, 5.06 and 4.54, respectively, ranking 3rd, 4th, and 5th. As can be seen in Table 8, these top five countries rank in the same order according to all three indicators.

1 The USA: **22.13**

2 China: **10.92**

3 Canada: **6.15**

4 France: **5.06**

5 The UK: **4.54**

Table 8. **The score and rank of Top 5 countries based on RLI_{Cik}, $RFOI_{Cik}$ and $RFII_{Cik}$ in the area of "Geosciences"**

Indicators	Score					Rank				
	USA	China	Canada	France	UK	USA	China	Canada	France	UK
RLI_{Cik}	22.13	10.92	6.15	5.06	4.54	1	2	3	4	5
$RFOI_{Cik}$	11.76	6.33	2.83	2.61	2.53	1	2	3	4	5
$RFII_{Cik}$	10.37	4.58	3.32	2.45	2.01	1	2	3	4	5

3.4 CLINICAL MEDICINE: The USA is far ahead; UK, Germany, Canada and France rank 2nd to 5th; and China entered the top 10 in 9th place

In the area of "Clinical medicine", the USA scores 41.31 in RLI_{Cik}, far ahead of other countries. The UK and Germany register at 21.38 and 14.03, respectively. China scores 7.11, ranking 9th, and displaying an obvious gap with other powers in this area.

The respective rankings of the USA, UK, Germany, and France in RLI_{Cik} are identical to that in $RFOI_{Cik}$ and $RFII_{Cik}$. China's placements vary slightly according to the three indicators: the country ranks the 9th in $RL_{ICi}k$, 7th in $RFOI_{Cik}$, and 10th in $RFII_{Cik}$, demonstrating that China currently lacks important, high-impact achievements in this area.

1 The USA: **41.31**

2 The UK: **21.38**

3 Germany: **14.03**

9 China: **7.11**

Table 9. **The score and rank of Top 5 countries and China based on RLI_{Cik}, $RFOI_{Cik}$ and $RFII_{Cik}$ in the area of "Clinical medicine"**

Indicators	Score						Rank					
	USA	UK	Germany	Canada	France	China	USA	UK	Germany	Canada	France	China
RLI_{Cik}	41.31	21.38	14.03	10.15	10.08	7.11	1	2	3	4	5	9
$RFOI_{Cik}$	21.33	10.43	6.79	4.72	4.96	4.01	1	2	3	6	5	7
$RFII_{Cik}$	19.98	10.95	7.24	5.44	5.12	3.10	1	2	3	4	5	10

3.5 BIOLOGICAL SCIENCES: The USA leads substantially, China has jumped to 2nd, and the UK, Italy, and Germany rank 3rd to 5th

In the area of "Biological sciences", the USA scores 28.28 in RLI_{Cik}, more than twice the mark posted by China, placing it 1st. China scores 12.36, ranking 2nd and showing significant progress. The UK, Italy, and Germany score 9.78, 5.27 and 4.84, respectively. The USA, China, the UK, and Italy maintain the same rank order according to the three indicators, while Germany's score in $RFII_{Cik}$ places it 7th.

1	2	3	4	5
The USA: **28.28**	China: **12.36**	The UK: **9.78**	Italy: **5.27**	Germany: **4.84**

Table 10. The score and rank of Top 5 countries based on RLI_{Cik}, $RFOI_{Cik}$ and $RFII_{Cik}$ in the area of "Biological sciences"

Indicators	Score					Rank				
	USA	China	UK	Italy	Germany	USA	China	UK	Italy	Germany
RLI_{Cik}	28.28	12.36	9.78	5.27	4.84	1	2	3	4	5
$RFOI_{Cik}$	14.62	6.96	5.20	2.88	2.71	1	2	3	4	5
$RFII_{Cik}$	13.65	5.40	4.58	2.40	2.13	1	2	3	4	7

3.6 CHEMISTRY AND MATERIALS SCIENCE: China's RLI_{Cik} is twice as that of the USA, China and the USA have respective advantages in specific Research Fronts; Germany, Singapore and UK rank 3rd to 5th

In the area of "Chemistry and materials science," China's RLI_{Cik} score is 26.53, twice that of the USA, earning China 1st place (Table 11). The USA scores 13.03, ranking 2nd. These scores indicate a significant activity gap between the USA and China. Germany, Singapore and the UK post marks of 4.44, 4.21, and 4.02 respectively, ranking 3rd to 5th. The rankings based on the indicators RLI_{Cik}, $RFOI_{Cik}$ and $RFII_{Cik}$ for China and USA are exactly the same, while the placements for Germany, Singapore and the UK vary slightly across the indicators.

1	2	3	4	5
China: **26.53**	The USA: **13.03**	Germany: **4.44**	Singapore: **4.21**	The UK: **4.02**

Table 11. The score and rank of Top 5 countries based on RLI_{Cik}, $RFOI_{Cik}$ and $RFII_{Cik}$ in the area of "Chemistry and materials science"

Indicators	Score					Rank				
	China	USA	Germany	Singapore	UK	China	USA	Germany	Singapore	UK
RLI_{Cik}	26.53	13.03	4.44	4.21	4.02	1	2	3	4	5
$RFOI_{Cik}$	15.45	6.86	2.42	1.83	2.15	1	2	3	5	4
$RFII_{Cik}$	11.08	6.17	2.02	2.37	1.87	1	2	4	3	5

3.7 PHYSICS: The USA leads in all areas; China overtakes Germany for 2nd place; the UK and Switzerland are 4th and 5th

In the area of "Physics," the USA posts the highest degree of activity with an RLI_{Cik} of 18.68, twice that of China. China and Germany score 9.43 and 7.96, respectively. The UK and Switzerland rank 4th and 5th with respective scores of 5.24 and 3.62. The USA, China, Germany, and the UK rank the same across all three indicators, while Switzerland scores outside the top five on one measure.

1 The USA: **18.68**

2 China: **9.43**

3 Germany: **7.96**

4 The UK: **5.24**

5 Switzerland: **3.62**

Table 12. The score and rank of Top 5 countries based on RLI_{Cik}, $RFOI_{Cik}$ and $RFII_{Cik}$ in the area of "Physics"

Indicators	Score					Rank				
	USA	China	Germany	UK	Switzerland	USA	China	Germany	UK	Switzerland
RLI_{Cik}	18.68	9.43	7.96	5.24	3.62	1	2	3	4	5
$RFOI_{Cik}$	9.77	5.95	4.67	2.54	1.74	1	2	3	4	6
$RFII_{Cik}$	8.90	3.48	3.29	2.70	1.88	1	2	3	4	5

3.8 ASTRONOMY AND ASTROPHYSICS: The USA has a dominant position; Germany, the UK, Japan, and France rank 2nd to 5th; and China ranks 11th

In the area of "Astronomy and astrophysics", the USA ranks 1st, with an RLI_{Cik} score of 30.98. Germany ranks 2nd with a mark of 17.13, with the UK 3rd at 16.28, followed by Japan (11.25) and France (11.12). China places 11th with a score of 6.91. Although China's performance is not outstanding, the country has made significant progress in the field, compared with last year's 19th position.

1	2	3	4	5
The USA: **30.98**	Germany: **17.13**	The UK: **16.28**	Japan: **11.25**	France: **11.12**

Table 13. The score and rank of Top 5 countries and China based on RLI_{Cik}, $RFOI_{Cik}$ and $RFII_{Cik}$ in the area of "Astronomy and astrophysics"

Indicators	Score						Rank					
	USA	Germany	UK	Japan	France	China	USA	Germany	UK	Japan	France	China
RLI_{Cik}	30.98	17.13	16.28	11.25	11.12	6.91	1	2	3	4	5	11
$RFOI_{Cik}$	16.87	8.71	8.54	5.65	5.49	3.81	1	2	3	4	5	10
$RFII_{Cik}$	14.11	8.42	7.74	5.59	5.63	3.10	1	2	3	5	4	12

3.9 MATHEMATICS, COMPUTER SCIENCE AND ENGINEERING: China is the most active, the USA is 2nd, while Saudi Arabia, the UK, and Turkey are 3rd to 5th

In the area of "Mathematics, computer science and engineering," China achieves the most active performance and ranks 1st, with a score of 33.55, about three times that of USA. Meanwhile, the USA posts a score of 10.75, ranking 2nd. Saudi Arabia, the UK, and Turkey score 6.00, 4.99 and 3.79 respectively, ranking 3rd to 5th. The ranking of the top 5 countries according to the three indicators is completely consistent.

1	2	3	4	5
China: **33.55**	The USA: **10.75**	Saudi Arabia: **6.00**	The UK: **4.99**	Turkey: **3.79**

Table 14. **The score and rank of Top 5 countries based on RLI_{Cik}, $RFOI_{Cik}$ and $RFII_{Cik}$ in the area of "Mathematics, computer science and engineering"**

Indicators	Score					Rank				
	China	USA	Saudi Arabia	UK	Turkey	China	USA	Saudi Arabia	UK	Turkey
RLI_{Cik}	33.55	10.75	6.00	4.99	3.79	1	2	3	4	5
$RFOI_{Cik}$	19.94	5.92	3.13	2.73	2.08	1	2	3	4	5
$RFII_{Cik}$	13.62	4.83	2.87	2.26	1.71	1	2	3	4	5

3.10 ECONOMICS, PSYCHOLOGY AND OTHER SOCIAL SCIENCES: The USA has obvious advantages, while China is in the 2nd place, rising steadily; the UK, Germany and the Netherlands rank 3rd to 5th

In this area of "Economics, psychology and other social sciences," the USA demonstrates the highest level of activity, earning 1st place with an RLI_{Cik} score of 15.53. China posts a mark of 9.23, ranking 2nd. The UK, Germany and the Netherlands score 6.30, 6.11, and 5.58, ranking 3rd to 5th, respectively. The USA, China, and Germany rank 1st, 2nd and 4th according to all three indicators, while the UK and the Netherlands swap 3rd and 5th positions between the $RFOI_{Cik}$ and be$RFII_{Cik}$ indicators.

1 The USA: **15.53**

2 China: **9.23**

3 The UK: **6.30**

4 Germany: **6.11**

5 The Netherlands: **5.58**

Table 15. **The score and rank of Top 5 countries based on RLI_{Cik}, $RFOI_{Cik}$ and $RFII_{Cik}$ in the area of "Economics, psychology and other social sciences"**

Indicators	Score					Rank				
	USA	China	UK	Germany	Netherlands	USA	China	UK	Germany	Netherlands
RLI_{Cik}	15.53	9.23	6.30	6.11	5.58	1	2	3	4	5
$RFOI_{Cik}$	8.29	5.64	3.44	2.94	2.38	1	2	3	4	5
$RFII_{Cik}$	7.24	3.58	2.86	3.17	3.20	1	2	5	4	3

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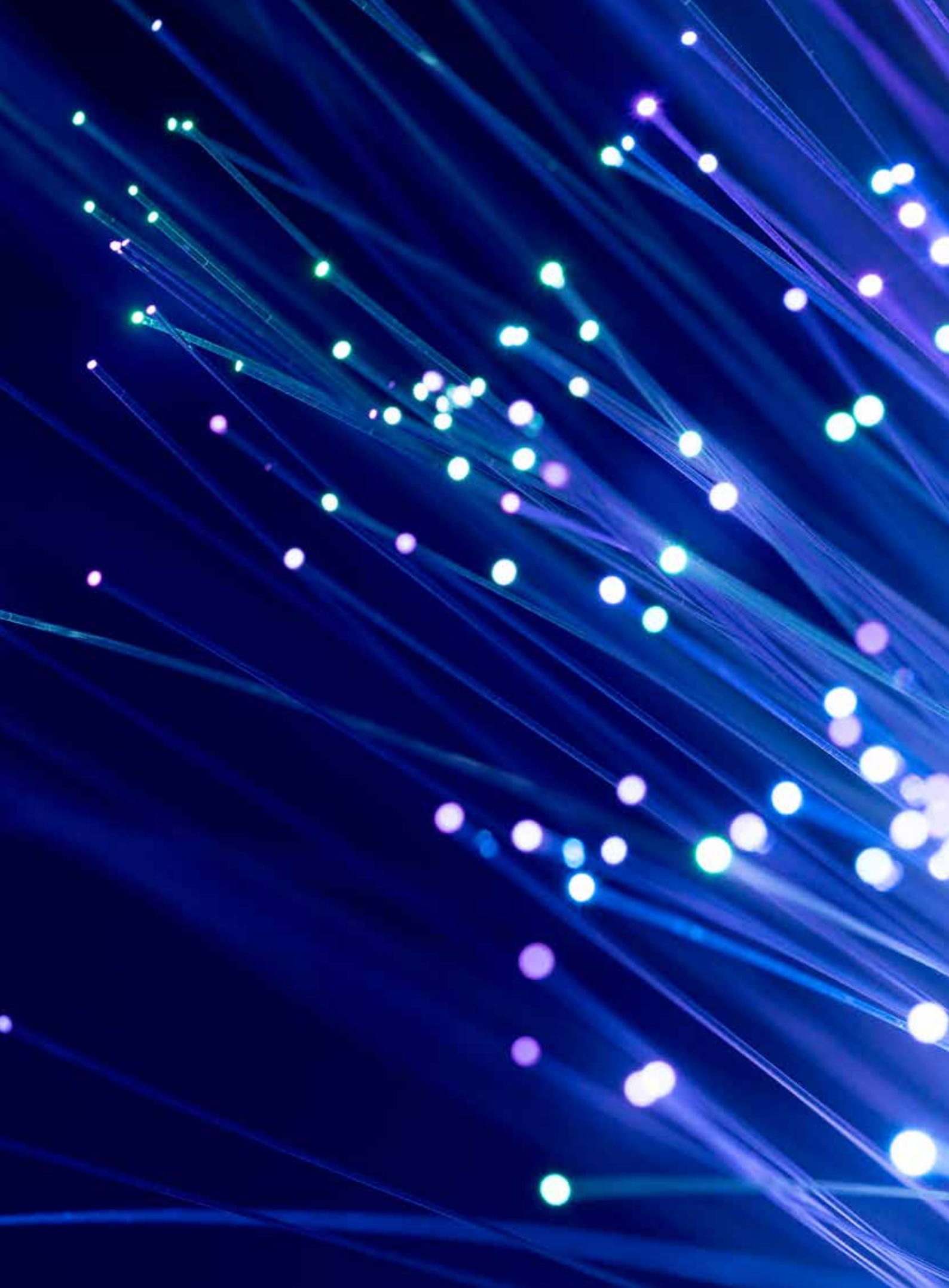

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