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2020 Research Fronts: Active Fields, Leading Countries

Institutes of Science and Development, Chinese Academy of Sciences

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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 2020" report is a prequel to another survey, "Research Fronts 2020: Active Fields, Leading Countries," having selected and discussed 110 hot fronts and 38 emerging fronts in 11 broad research areas. Based on the findings of "Research Fronts 2020," 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.

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.

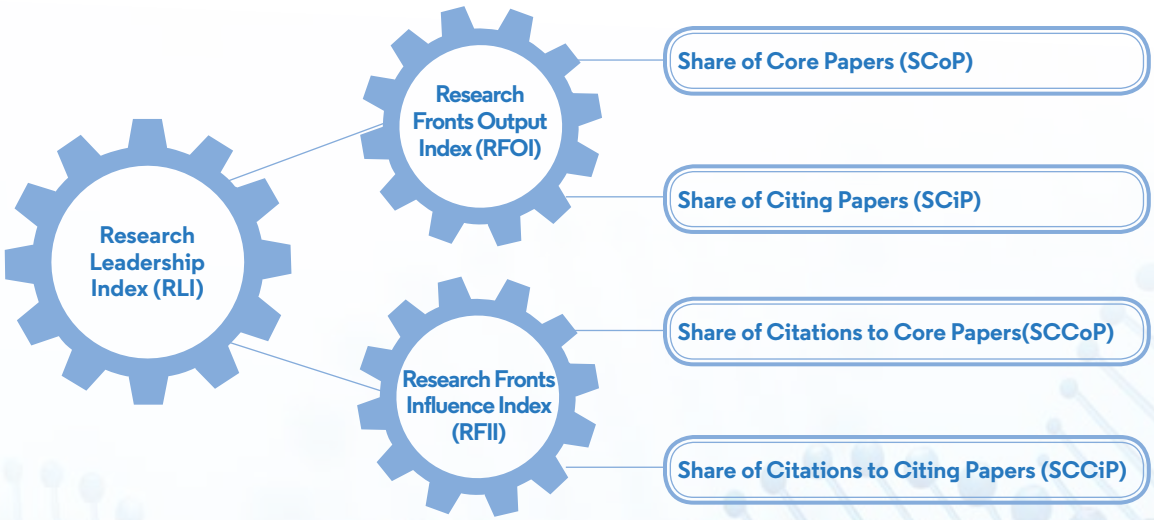


Fig. 1. The logic model of Research Leadership Index (RLI)

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 11 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 11 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 the Research Fronts Output Index of a country, $RFII_{Cij}$ is the Research Fronts Influence Index of a country; j represents the Research Front, and 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 to a Research Front. $RFOI_{Cij}$ is equal to the sum of the two indicators $SCoP_{Cij}$ and $SCiP_{Cij}$

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

A 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 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.

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

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 to a Research Front. $RFII_{Cij}$ is equal to the sum of the two indicators $SCCoP_{Cij}$ and $SCCiP_{Cij}$.

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

A 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.

A country's Share of Citations to Citing Papers 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 follows:

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

RLI_{Cik} 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 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 Papers 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 Papers in an area ($SCiP_{Cik}$) is as follows:

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

(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. $RFII_{Cik}$ is 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 as follows:

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

1.2.3 Research Leadership Index of a country in 11 broad research areas (RLI_{Ci})

The Research Leadership Index of a country in 11 broad research areas (RLI_{Ci}) represents the scores of RLI_{Cik} of 11 broad research areas added together. The index is a comprehensive evaluation index to measure the degree of activity of a country based on its contribution to 11 broad research areas composed of 148 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 11 broad research areas ($RFOI_{Ci}$)

The Research Fronts Output Index of a country in 11 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 11 broad research areas comprising 148 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 11 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 11 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 11 broad research areas ($RFII_{Ci}$)

The Research Fronts Influence Index of a country in 11 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 11 broad research areas comprising 148 Research Fronts. $RFII_{Ci}$ is equal to the sum of the two indicators $SCCoP_{Ci}$ and $SCCiP_{Ci}$.

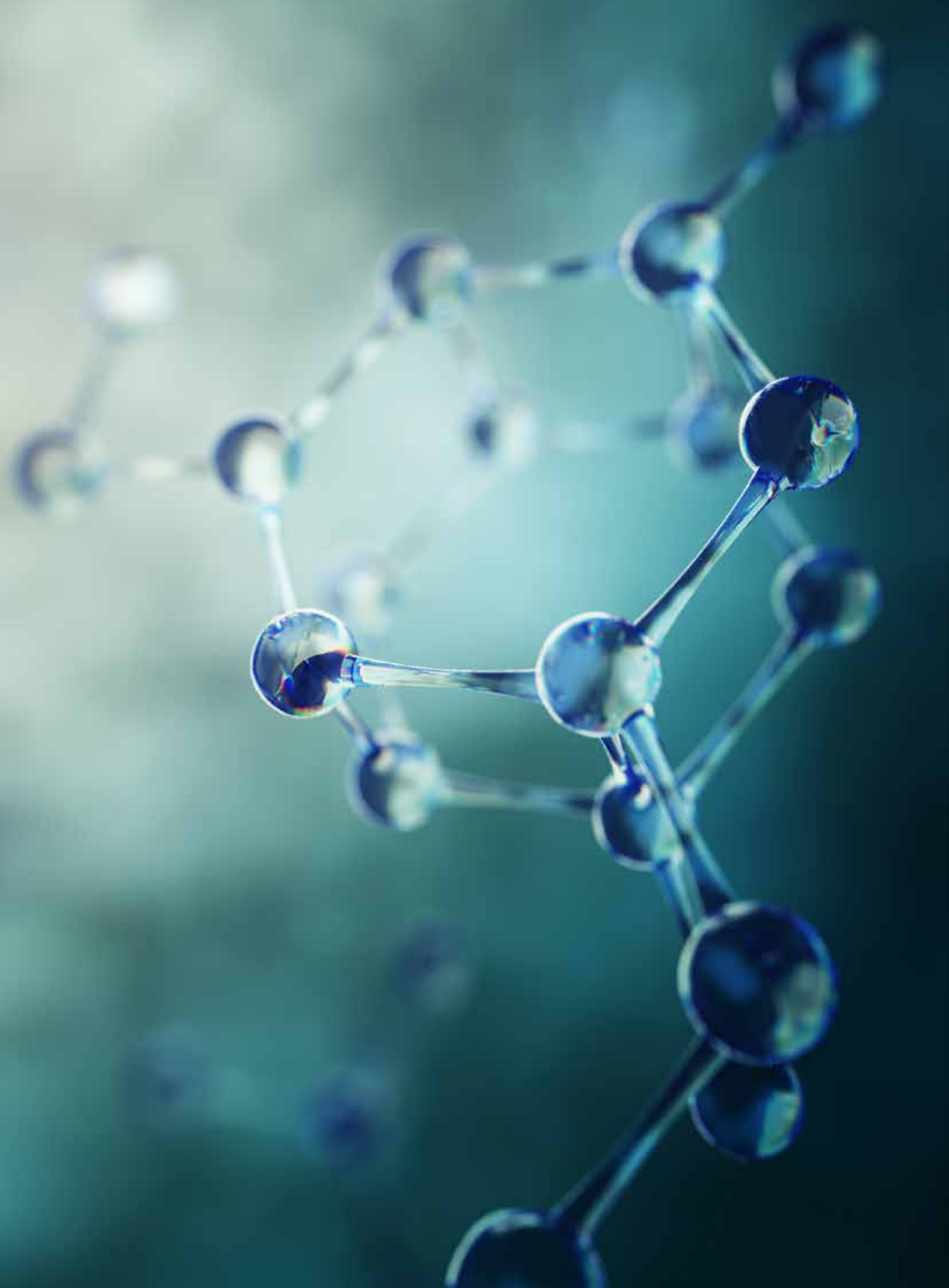
$$\mathrm{RFII}_{Ci} = \mathrm{SCCoP}_{Ci} + \mathrm{SCCiP}_{Ci} = \sum_{k=1}^{10}\sum_{j=1}^{n}\frac{CoC_{ij}}{CoC_j} + \sum_{k=1}^{10}\sum_{j=1}^{n}\frac{CiC_{ij}}{CiC_j}$$

The formula for a country's Share of Citations to Core Papers in 11 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 11 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 11 broad research areas comprising 148 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 11 broad research areas comprising 148 Research Fronts, the USA is the most active, with an RLI_{ci} score of 226.63, ranking 1st. China ranks 2nd with a score of 151.29. The UK and Germany score 77.81 and 73.86, respectively, ranking 3rd and 4th. The RLIci scores for France, Canada, Australia, the Netherlands, Italy, and Spain register between 50.00 and 30.00, ranking those nations from 5th to 10th, with Japan (at 29.53) ranking 12th.

Fig 2. Research Leadership Index (RLI_{Ci}) of Top 20 Countries in 11 broad research areas with 148 Research Fronts

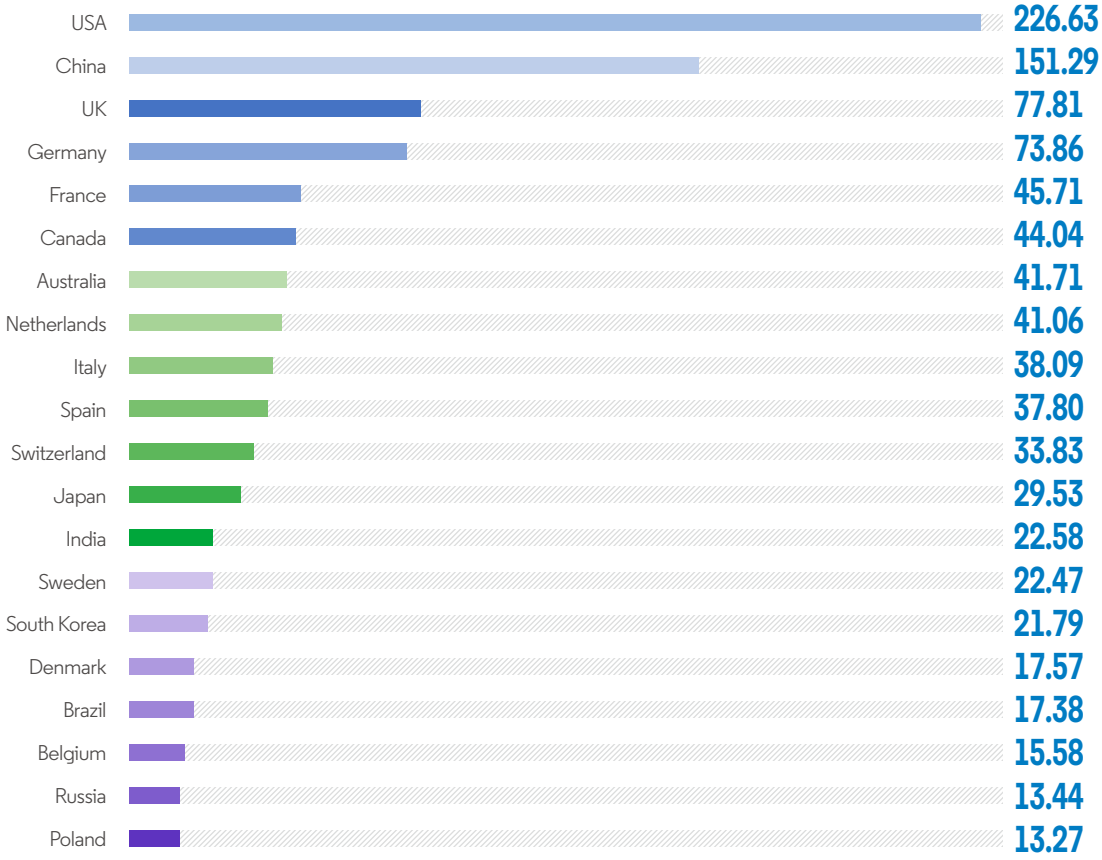


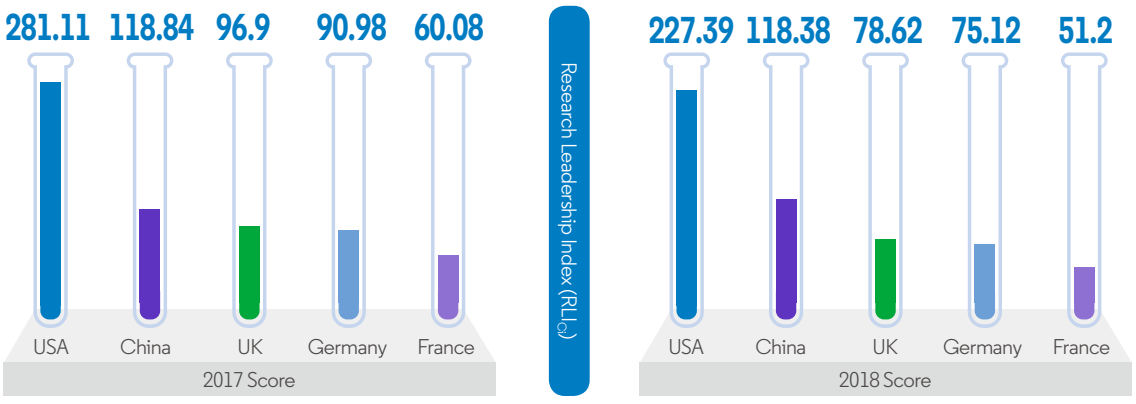
Table 1 shows that the rank order for the three indicators RLI_{Ci}, $RFOI_{Ci}$ and $RFII_{Ci}$ for the top four countries is the same. For the remaining countries, scores on the three indicators do not differ widely, although precise calculation ranks the nations from 5th to 20th.

Table 1. The Research Leadership Index (RLI_{Ci}) of Top 20 Countries in 11 broad research areas with 148 Research Fronts

Country	RLI_{Ci}		$RFOI_{Ci}$		$RFII_{Ci}$	
	Score	Rank	Score	Rank	Score	Rank
USA	226.63	1	119.58	1	107.04	1
China	151.29	2	90.70	2	60.59	2
UK	77.81	3	40.43	3	37.38	3
Germany	73.86	4	37.54	4	36.32	4
France	45.71	5	23.44	5	22.27	6
Canada	44.04	6	21.66	6	22.38	5
Australia	41.71	7	20.31	8	21.40	7

Country	RLI_{Ci}		$RFOI_{Ci}$		$RFII_{Ci}$	
	Score	Rank	Score	Rank	Score	Rank
Netherlands	41.06	8	20.10	9	20.95	8
Italy	38.09	9	20.41	7	17.68	10
Spain	37.80	10	19.21	10	18.59	9
Switzerland	33.83	11	16.77	11	17.06	11
Japan	29.53	12	16.17	12	13.35	12
India	22.58	13	12.74	13	9.85	15
Sweden	22.47	14	11.02	15	11.45	13
South Korea	21.79	15	11.56	14	10.23	14
Denmark	17.57	16	8.73	16	8.85	17
Brazil	17.38	17	8.15	17	9.22	16
Belgium	15.58	18	7.27	18	8.32	18
Russia	13.44	19	6.91	19	6.53	21
Poland	13.27	20	6.13	21	7.14	19

Table 2 compares the Research Leadership Index (RLI_{Ci}) of the top five countries in 2017, 2018, 2019, and 2020, and the proportion relative to the USA. The top five countries in the four years are completely the same. The USA scores 281.11, 227.39, 204.89, and 226.63, respectively in the four years, maintaining 1st place. China ranks 2nd with 118.84, 118.38, 139.68, and 151.29 points in four 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 100.00% per year. The ratio of China to the USA is 42.28%, 52.06%, 68.18%, and 66.76% for the four years. Thus, we find that the proportion of China to the USA is increasing from 2017 to 2019, and keeping steady from 2019 to 2020. Meanwhile, the UK, Germany, and France rank 3rd to 5th from 2017 to 2020, but the proportion changes slightly compared with the USA.



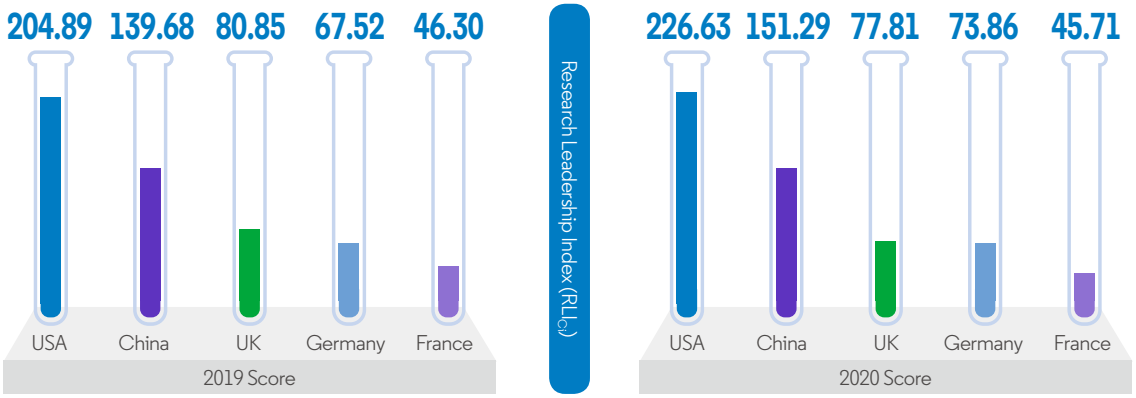


Table 2. Research Leadership Index (RLI_{Ci}) for Top 20 Countries in all* broad research areas with Top Research Fronts, for each of four years, 2017 to 2020

Country	RLI_{Ci}							
	2017 Score	2017 %	2018 Score	2018 %	2019 Score	2019 %	2020 Score	2020 %
USA	281.11	100.00%	227.39	100.00%	204.89	100.00%	226.63	100.00%
China	118.84	42.28%	118.38	52.06%	139.68	68.18%	151.29	66.76%
UK	96.9	34.47%	78.62	34.57%	80.85	39.46%	77.81	34.33%
Germany	90.98	32.36%	75.12	33.04%	67.52	32.95%	73.86	32.59%
France	60.08	21.37%	51.2	22.52%	46.30	22.60%	45.71	20.17%

2.2 The USA is leading seven areas, while China has outstanding performance in four areas, but lags in two

For the 11 broad research areas, the USA's RL_{ICi} scores are 1st in seven of the main areas (and by a notably wide margin), except for four areas: "Agricultural, plant and animal sciences", "Chemistry and materials science", "Mathematics", and "Information science". In all four of the latter, China ranks 1st. China ranks 2nd in three areas: "Ecology and environmental science", "Physics," and "Economics, psychology and other social sciences", with outstanding performance. China ranks 3rd and 5th in two areas: "Biological science" and "Geosciences". China, however, ranks 12th and 8th in the areas of "Clinical medicine" and "Astronomy and astrophysics", showing that the nation still has ground to gain in those two broad specialties.

* In Research Fronts 2017-2019, 21 ESI fields were classified into 10 broad research areas. In Research Fronts 2020, 21 ESI fields were classified into 11 broad research areas. The broader area of Mathematics, Computer Science and Engineering in previous reports has been split into two areas: Mathematics, and Information Science. The field of Engineering is no longer covered.

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

Countries	11 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		Information science		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	Score	Rank
USA	226.63	1	7.90	2	15.38	1	22.74	1	53.27	1	37.28	1	14.73	2	19.14	1	23.23	1	10.42	2	9.27	2	13.27	1
China	151.29	2	15.16	1	11.92	2	5.55	5	7.10	12	12.87	3	39.49	1	12.43	2	6.80	8	15.98	1	14.97	1	9.03	2
UK	77.81	3	4.84	3	3.30	6	6.29	3	19.95	2	13.92	2	1.88	6	3.36	6	12.35	3	0.98	13	4.77	3	6.17	3
Germany	73.86	4	3.47	7	4.47	3	6.14	4	17.89	3	10.22	4	2.81	4	6.22	4	14.95	2	2.01	6	1.52	11	4.15	4
France	45.71	5	2.28	11	2.68	8	6.67	2	12.13	4	2.80	18	1.13	11	2.68	9	11.47	4	0.42	24	1.57	10	1.88	12
Canada	44.04	6	3.70	6	2.55	9	5.05	6	10.37	5	6.26	7	0.91	13	2.47	11	5.28	12	1.28	12	3.83	4	2.35	9
Australia	41.71	7	2.77	9	3.44	5	3.24	9	10.10	6	7.91	5	1.60	7	1.43	17	5.86	10	0.51	19	2.23	6	2.63	8
Netherlands	41.06	8	1.48	15	2.46	10	3.24	8	9.38	7	7.34	6	1.22	9	2.85	8	9.07	6	0.41	25	0.45	21	3.14	6
Italy	38.09	9	3.93	4	1.62	14	2.83	10	7.95	9	5.67	9	0.58	16	2.94	7	9.58	5	0.47	22	0.51	19	2.02	11
Spain	37.80	10	3.91	5	1.76	11	3.57	7	8.12	8	4.43	11	0.42	18	2.34	12	8.84	7	0.58	17	0.55	16	3.26	5
Switzerland	33.83	11	0.96	20	2.91	7	2.82	11	7.54	11	5.29	10	0.84	14	3.75	5	6.48	9	0.53	18	1.74	9	0.97	18
Japan	29.53	12	1.24	17	0.91	21	2.05	14	7.68	10	1.70	23	1.16	10	6.34	3	5.85	11	0.28	30	1.35	12	0.97	19
India	22.58	13	2.31	10	3.91	4	1.61	16	2.16	25	2.18	22	1.05	12	1.04	19	3.28	21	1.33	11	2.03	7	1.68	13
Sweden	22.47	14	0.21	42	1.67	13	1.33	17	5.18	14	6.05	8	0.22	21	1.78	14	4.47	14	0.12	42	0.25	29	1.21	16
South Korea	21.79	15	1.59	14	0.98	19	1.23	20	3.90	19	2.56	19	2.14	5	2.32	13	3.46	19	0.76	16	1.87	8	0.98	17
Denmark	17.57	16	0.60	27	0.87	22	1.16	21	6.99	13	3.58	14	0.09	28	0.49	27	2.58	23	0.09	46	0.88	14	0.25	36
Brazil	17.38	17	1.65	13	0.59	26	0.34	32	5.15	15	1.28	28	0.07	32	1.40	18	3.76	18	0.16	39	0.17	35	2.79	7
Belgium	15.58	18	1.32	16	0.77	24	1.06	22	3.68	20	3.31	15	0.10	27	0.45	30	4.07	16	0.13	41	0.14	36	0.56	23
Russia	13.44	19	0.93	21	0.49	28	0.77	27	3.59	21	0.82	32	0.16	22	1.68	15	2.98	22	1.69	7	0.20	32	0.14	47
Poland	13.27	20	1.08	19	0.37	32	0.10	42	4.00	18	1.37	26	0.08	30	0.91	20	4.77	13	0.32	29	0.08	40	0.19	43

Among the 110 hot Research Fronts and 38 emerging Research Fronts in 11 broad research areas, the USA ranks 1st in 79, accounting for 53.38% of the148 Research Fronts. China earns the top spot in 42 fronts, or 28.38%. The UK is tops in 10 Research Fronts, Germany ranks 1st in 4, while France can claim the top ranking in one front (Table 4).

Of the 11 broad research areas, "Mathematics", "Information science", "Chemistry and materials science", and "Agricultural, plant and animal sciences" are the four most advanced areas for China, with the country ranking 1st in more than 45.00% (87.50%, 60.00%, 50.00%, and 45.45%, respectively) of the Research Fronts within each of those four broad groupings, with proportions higher than those of the USA. In the area of "Ecology and environmental science", China ranks 1st in four Research Fronts while the USA registers 1st in five Research Fronts, so China underperforms the USA by a slight margin in this area. In the area of "Biological science", China ranks 1st in three Research Fronts, while the USA claims the top spot in 15 fronts, posting a considerable gap over China. Similar gaps are evident in "Physics" and "Economics, psychology and other social sciences", with China scoring 1st in two fronts in both those fields, while the USA registers 1st in 10 and six fronts, respectively. In the area of "Geoscience", China registers 1st in one Research Front, compared with the USA scoring first in eight, another significant difference in performance. Even more strikingly, China does not rank 1st in any of the fronts within "Clinical medicine" and "Astronomy and astrophysics", while the USA attains that mark in, respectively, 19 and 10 fronts – a substantial difference in performance between the two countries.

Compared with China, the USA accounts for 1st-place rankings in less than 20% of the Research Fronts in these four areas: "Chemistry and materials science", "Mathematics", "Information science", and "Agricultural, plant and animal sciences". Meanwhile, those four specialties are highly active in terms of Chinese representation.

In addition to the above three fields, the USA claims 1st-place performance in more than 70.00% of the Research Fronts in each of these five areas: "Geoscience," "Clinical medicine," "Biological science," "Physics," "Astronomy and astrophysics," – the best showing among all countries.

In "Ecology and environmental sciences" and "Economics, psychology and other social sciences" the USA ranks 1st in 45.45% and 46.15% of the Research Fronts.

The USA and China accounts for 1st-place rankings in about 80.00% of the 148 fronts in the 11 broad research areas, while the UK and Germany share about 10.00% of the total, and the other 10.00% is shared by 11 countries.

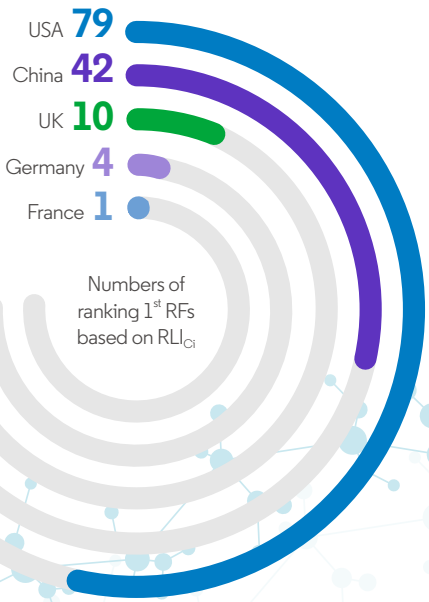


Table 4. The numbers and ratios of the Research Fronts in which the respective Top 5 countries rank first, out of 148 fronts in 11 broad research areas (based on RLI_{Ci})

Areas	Numbers of RFs	Numbers of ranking 1st RFs					Ratios				
		USA	China	UK	Germany	France	USA	China	UK	Germany	France
11 broad research areas total	148	79	42	10	4	1	53.38%	28.38%	6.76%	2.70%	0.68%
Agricultural, plant and animal sciences	11	1	5	2	0	0	9.09%	45.45%	18.18%	0.00%	0.00%
Ecology and environmental sciences	11	5	4	1	0	0	45.45%	36.36%	9.09%	0.00%	0.00%
Geosciences	11	8	1	0	1	0	72.73%	9.09%	0.00%	9.09%	0.00%
Clinical medicine	24	19	0	3	0	1	79.17%	0.00%	12.50%	0.00%	4.17%
Biological sciences	19	15	3	0	0	0	78.95%	15.79%	0.00%	0.00%	0.00%
Chemistry and materials science	16	1	14	0	1	0	6.25%	87.50%	0.00%	6.25%	0.00%
Physics	12	10	2	0	0	0	83.33%	16.67%	0.00%	0.00%	0.00%
Astronomy and astrophysics	11	10	0	0	1	0	90.91%	0.00%	0.00%	9.09%	0.00%
Mathematics	10	2	5	0	1	0	20.00%	50.00%	0.00%	10.00%	0.00%
Information science	10	2	6	1	0	0	20.00%	60.00%	10.00%	0.00%	0.00%
Economics, psychology and other social sciences	13	6	2	3	0	0	46.15%	15.38%	23.08%	0.00%	0.00%

Among nations ranking among the top three performers in these Research Fronts (Table 5), the USA earns that distinction in 130 fronts, or 87.84%, China in 72 fronts (48.65%), the UK in 40, and Germany in 38. 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 27.03% and 25.68% of the total number of Research Fronts.

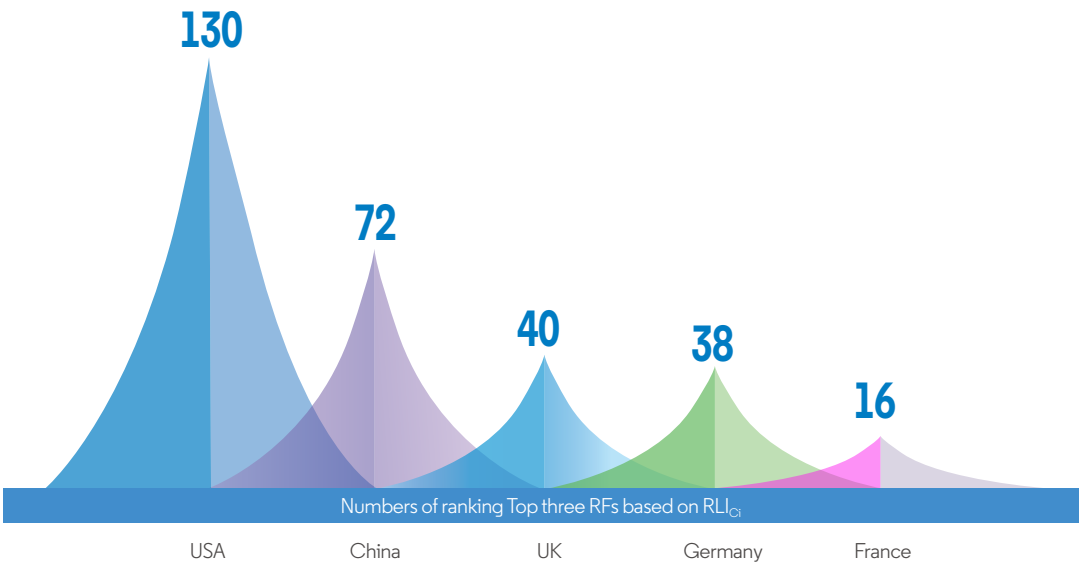


Table 5. The numbers and ratios of nations ranking among the top three performers in Research Fronts, among the Top 5 countries in 11 broad research areas with 148 Research Fronts (based on RLI_{Ci})

Areas	Numbers of RFs	Numbers of ranking Top three RFs					Ratios				
		USA	China	UK	Germany	France	USA	China	UK	Germany	France
11 broad research areas total	148	130	72	40	38	16	87.84%	48.65%	27.03%	25.68%	10.81%
Agricultural, plant and animal sciences	11	9	8	2	1	0	81.82%	72.73%	18.18%	9.09%	0.00%
Ecology and environmental sciences	11	9	8	1	2	2	81.82%	72.73%	9.09%	18.18%	18.18%
Geosciences	11	9	2	3	5	4	81.82%	18.18%	27.27%	45.45%	36.36%
Clinical medicine	24	23	4	10	7	5	95.83%	16.67%	41.67%	29.17%	20.83%
Biological sciences	19	17	6	9	6	0	89.47%	31.58%	47.37%	31.58%	0.00%
Chemistry and materials science	16	15	16	0	4	1	93.75%	100.00%	0.00%	25.00%	6.25%
Physics	12	12	9	1	3	0	100.00%	75.00%	8.33%	25.00%	0.00%
Astronomy and astrophysics	11	11	0	5	7	3	100.00%	0.00%	45.45%	63.64%	27.27%
Mathematics	10	6	5	1	1	0	60.00%	50.00%	10.00%	10.00%	0.00%
Information science	10	9	9	2	0	0	90.00%	90.00%	20.00%	0.00%	0.00%
Economics, psychology and other social sciences	13	10	5	6	2	1	76.92%	38.46%	46.15%	15.38%	7.69%

The USA makes the top three in more than 60% of the respective Research Fronts associated with all 11 broad research areas; they are higher than those in China (except for the area of "Chemistry and materials science"). That means the USA maintains a leading position in all areas. In the areas of "Physics" and "Astronomy and astrophysics," the USA ranks among the top three performers in 100% of the pertinent Research Fronts. This notably superior performance also carries over into "Clinical medicine," "Biological science" and "Information science" – all of the three areas in which the USA ranks among the top three in more than 90% of the Research Fronts.

In "Agricultural, plant and animal sciences", "Ecology and environmental science" and "Geosciences", the USA accounts for 81.82%. In "Economics, psychology and other social sciences", the USA is 76.92%. Meanwhile, in the area of "Mathematics", the USA's proportion of top-three placements ratio accounts for 60.00%.

In "Mathematics", China posts an impressive performance, earning top-three spots in 50.00% of the Research Fronts. In Figure 3, with "Mathematics" as the middle point, China ranks among the top three in more than half of the Research Fronts in the five areas on the upper half of part Figure 3. China's ratio of top three fronts in the five areas

on the lower half of Figure 3 are all below half.

In fact, comparatively speaking, China is the most active in the five areas on the upper half part of Figure 3, accounting for 100.00% of top-three placements in Research Fronts pertaining to "Chemistry and materials science", 90.00% in "Information science" and, respectively, 75.00%, 72.73% and 72.73% in "Physics", "Agricultural science, botany and zoology" and "Ecology and environmental science".

Among the five fields on the lower half part of Figure 3, in "Economics, psychology, and other social sciences" and "Biological science", China registers among the top three in 31.58% and 38.46% of the Research Fronts, respectively, and at 18.18% and 16. 67% in "Geosciences" and "Clinical medicine". But there are no top three fronts in "Astronomy and astrophysics".

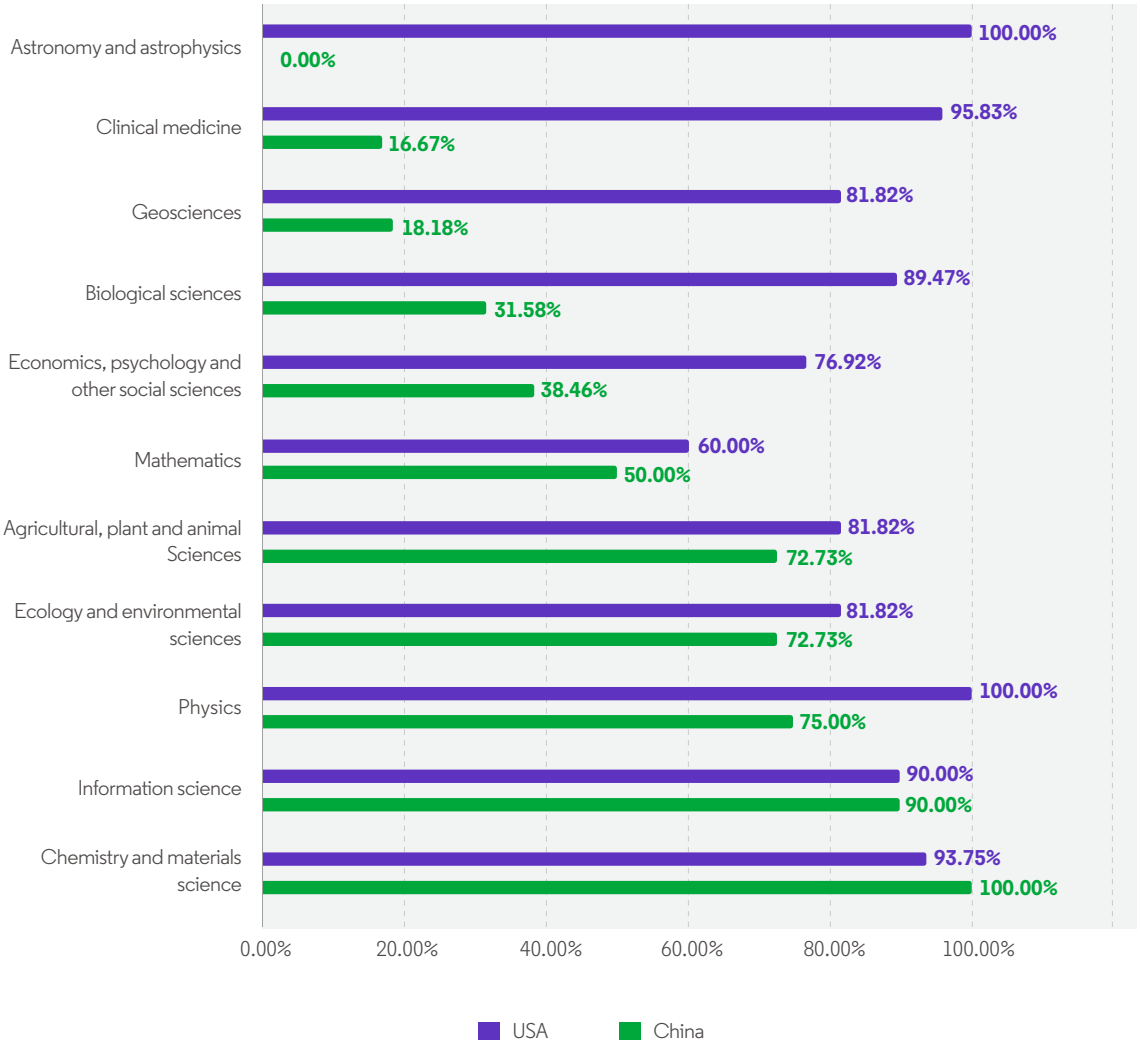


Fig 3. The ratios of the ranking Top three Research Fronts for China and USA in 11 broad research areas with 148 Research Fronts (based on RLI_{Ci})

The UK, meanwhile, places among the top three in 40.00%-50.00% of the Research Fronts in "Astronomy and astrophysics", "Clinical medicine", "Biological sciences" and "Economics, psychology and other social sciences". The UK ranks in the top three in 27.27% of Research Fronts in "Geosciences". These five areas are just the relatively weak areas in China. The proportion of the UK's top three in the other six areas is less than 20.00%, and the UK has no top-three showings in any fronts in the area of "Chemistry and materials 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.

In the area of "Astronomy and astrophysics", Germany has the highest proportion of top three Research Fonts, accounting for 63.64%. The second is "Geosciences", with 45.45% of the front ranking in the top three. In the four areas of "Economics, psychology and other social sciences", "Clinical medicine", "Physics" and "Chemistry and materials science", Germany's top three fronts account for 25.00% - 31.58%. The other five areas account for less than 20.00%, of which Germany does not rank the top three in the field of "Information science".

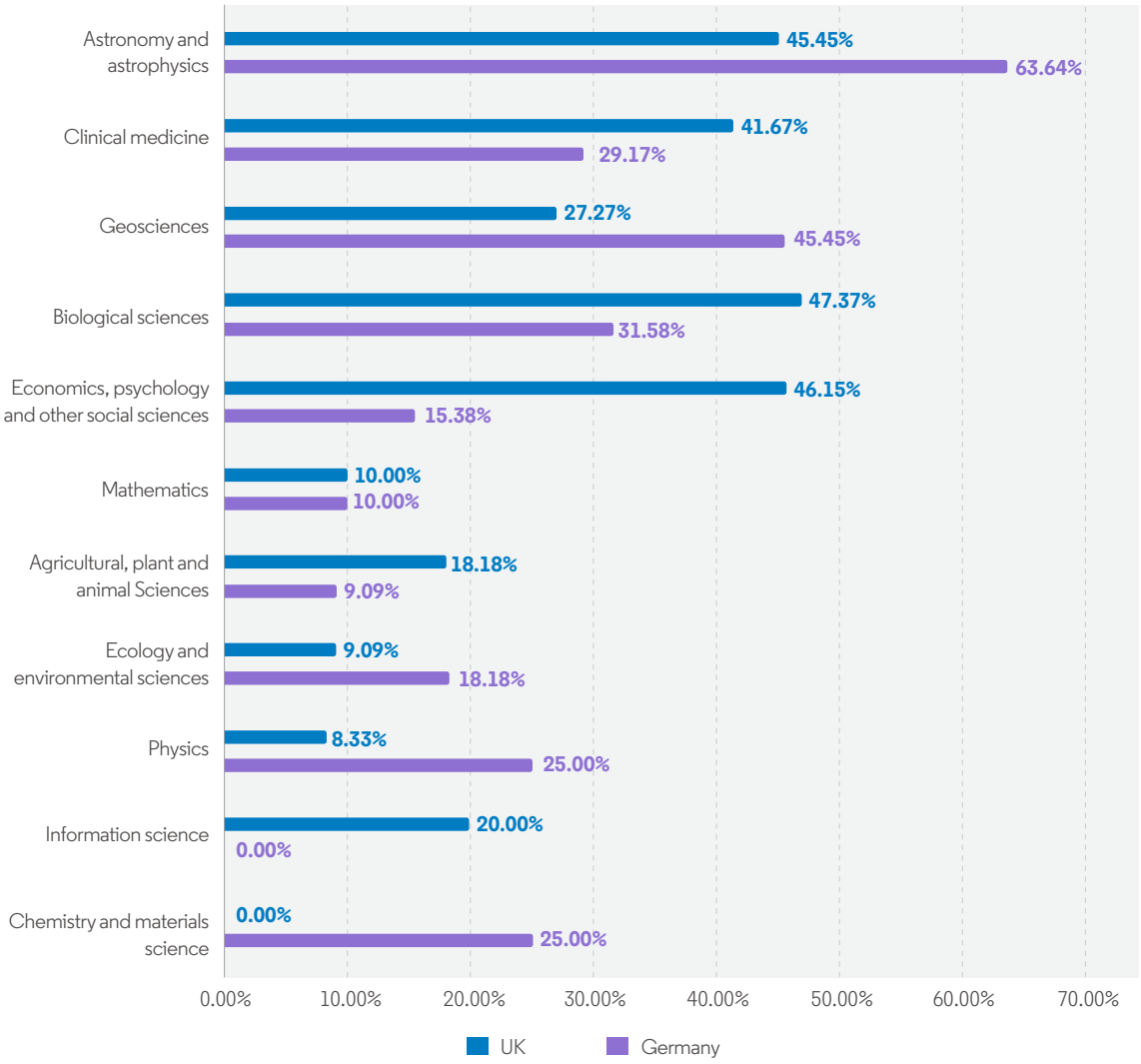


Fig 4. The ratios of Research Fronts in which the UK and Germany rank among the top three performers, in 11 broad research areas comprising 148 Research Fronts (based on RLI_{Ci})

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: China jumps to 1st; The USA is 2nd; UK, Italy and Spain are the 3rd, 4th and 5th

In the area of "Agricultural, plant and animal sciences," China is the most active according to its RLI_{Cik} score of 15.16, ranking 1st. The USA scores 7.90, ranking 2nd. the UK scores 4.84 for 3rd place, followed by Italy and Spain. As can be seen from Table 6, the ranking according to RLI_{Cik} and $RFOI_{Cik}$ is the same as RLI_{Cik} for China, the USA, and the UK. By contrast, the rankings for Italy and Spain vary slightly according to the $RFII_{Cik}$ indicators.

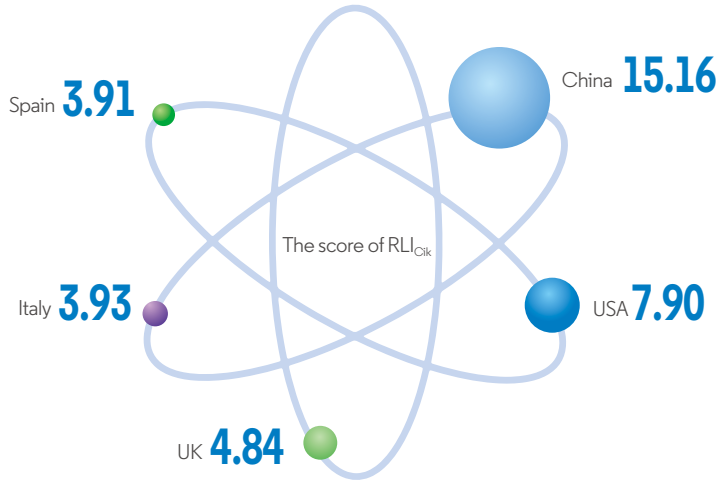


Table 6. The score and rank of Top 5 countries based on RLI_{Cik}, $RFOI_{Cik}$ and $RFII_{Cik}$ in the area of "Agricultural, plant and animal sciences"

Indicators	Score					Rank				
	China	USA	UK	Italy	Spain	China	USA	UK	Italy	Spain
RLI_{Cik}	15.16	7.90	4.84	3.93	3.91	1	2	3	4	5
$RFOI_{Cik}$	8.97	3.88	2.56	2.09	2.02	1	2	3	4	5
$RFII_{Cik}$	6.19	4.02	2.28	1.84	1.89	1	2	3	5	4

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

In the area of "Ecology and environmental sciences" (Table 7), the USA scores 15.38 in RLI_{Cik}, ranking 1st, demonstrating the most activity. China scores 11.92, ranking 2nd. In third place is Germany, with its score of 4.47 significantly lower than the top two. India and Australia rank 4th and 5th.

The rank order of China, the USA, and Australia remains the same for all three indicators: RL_{ICik}, $RFOI_{Cik}$ and $RFII_{Cik}$, while the rankings of the $RFOI_{Cik}$ indicator in Germany and India are inconsistent with the other two indicators.

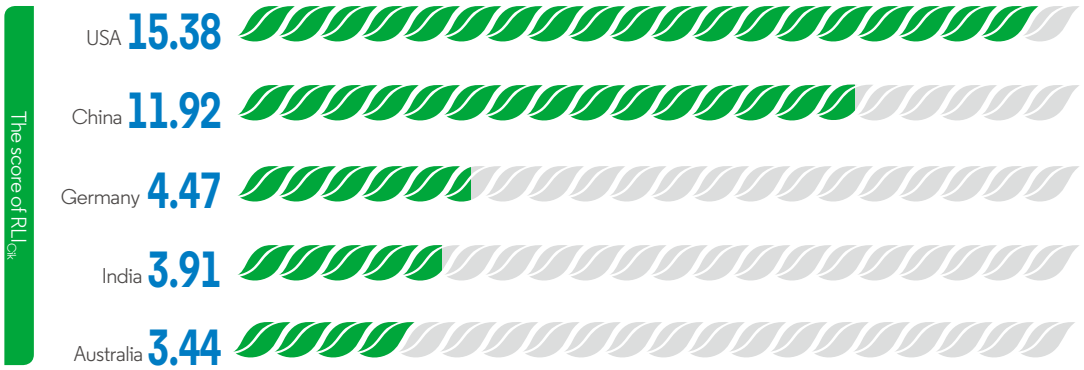


Table 7. The score and rank of Top 5 countries based on RLI_{Cik}, $RFOI_{Cik}$ and $RFII_{Cik}$ in the area of "Ecology and environmental sciences"

Indicators	Score					Rank				
	USA	China	Germany	India	Australia	USA	China	Germany	India	Australia
RLI_{Cik}	15.38	11.92	4.47	3.91	3.44	1	2	3	4	5
$RFOI_{Cik}$	8.35	7.14	2.04	2.23	1.80	1	2	4	3	5
$RFII_{Cik}$	7.03	4.78	2.44	1.68	1.64	1	2	3	4	5

3.3 Geosciences: The USA is the most active, France, UK, Germany and China are 2nd to 5th with a significant gap with the USA

In the area of "Geosciences", the USA scores 22.74 in RLI_{Cik}, ranking 1st, far ahead of other countries. France, the UK and Germany scored 6.67, 6.29 and 6.14 respectively, ranking 2nd to 4th, with a large gap compared to the USA. China scores 5.55, ranking 5th. As can be seen in Table 8, the USA and France rank in the same order according to all three indicators, while the other three countries are not completely consistent in their rankings.

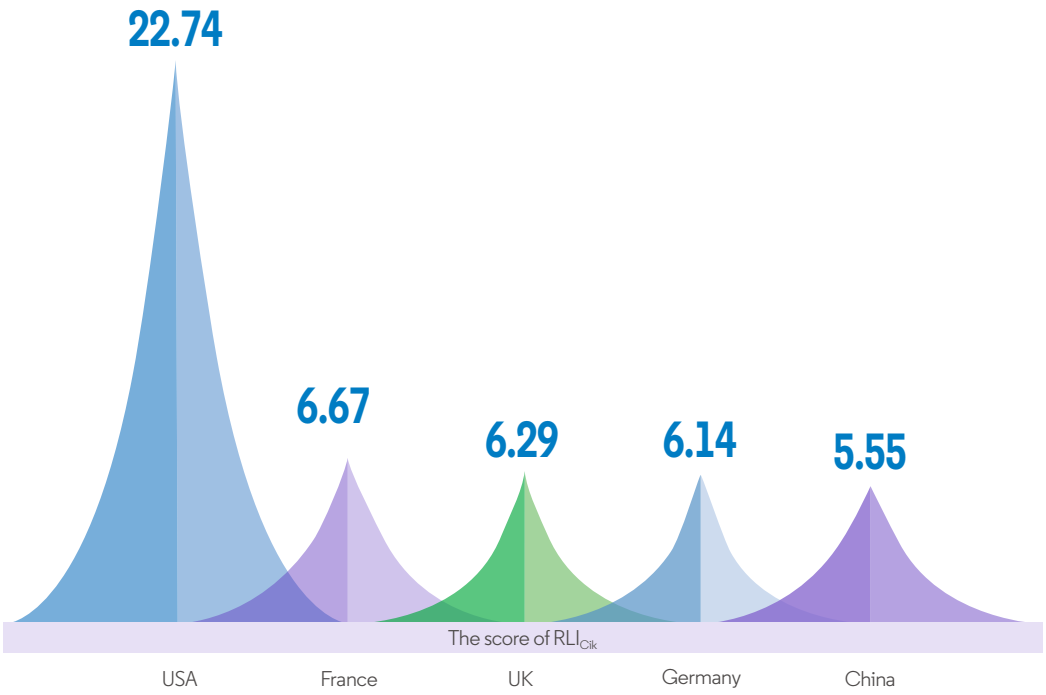


Table 8. The score and rank of Top 5 countries based on RLI_{Cik}, $RFOI_{Cik}$ and $RFII_{Cik}$ in the area of "Geosciences"

Indicators	Score					Rank				
	USA	France	UK	Germany	China	USA	France	UK	Germany	China
RLI_{Cik}	22.74	6.67	6.29	6.14	5.55	1	2	3	4	5
$RFOI_{Cik}$	12.73	3.74	3.64	3.45	3.68	1	2	4	5	3
$RFII_{Cik}$	10.01	2.93	2.65	2.70	1.87	1	2	4	3	6

3.4 CLINICAL MEDICINE: The USA is far ahead; UK, Germany, France, and Canada rank 2nd to 5th; and China is in 12th place

In the area of "Clinical medicine", the USA scores 53.27 in RLI_{Cik}, far ahead of other countries. The UK and Germany register at 19.95 and 17.89, respectively. France and Canada score 12.13 and 10.37, respectively, ranking 4th and 5th. China scores 7.10, ranking 12th and displaying a 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 12th in RLI_{Cik}, 7th in $RFOI_{Cik}$, and 15th in $RFII_{Cik}$, demonstrating that China currently lacks significant, high-impact achievements in this area.

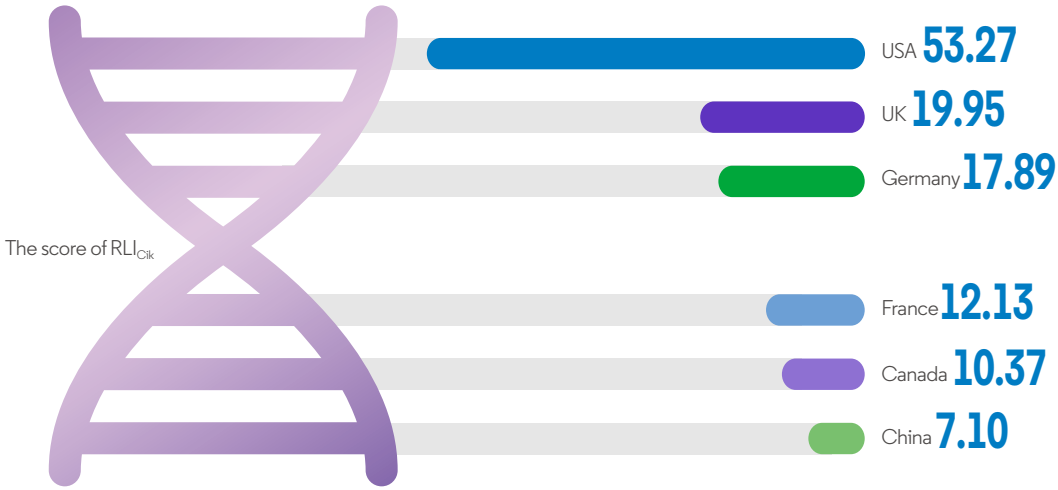


Table 9. The score and rank of Top 5 countries based on RLI_{Cik}, $RFOI_{Cik}$ and $RFII_{Cik}$ in the area of "Clinical medicine"

Indicators	Score						Rank					
	USA	UK	Germany	France	Canada	China	USA	UK	Germany	France	Canada	China
RLI_{Cik}	53.27	19.95	17.89	12.13	10.37	7.10	1	2	3	4	5	12
$RFOI_{Cik}$	27.25	9.68	8.91	5.82	4.45	4.50	1	2	3	4	9	7
$RFII_{Cik}$	26.03	10.27	8.98	6.30	5.92	2.60	1	2	3	4	5	15

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

In the area of "Biological sciences", the USA scores 37.28 in RLI_{Cik}, placing it 1st. The UK and China score roughly equally, 13.92 and 12.87 respectively, ranking 2nd and 3rd. Germany and Australia score 10.22 and 7.91, respectively. The USA and Australia maintain the same rank order according to the three indicators, while the scores vary for the UK, China, and Germany.

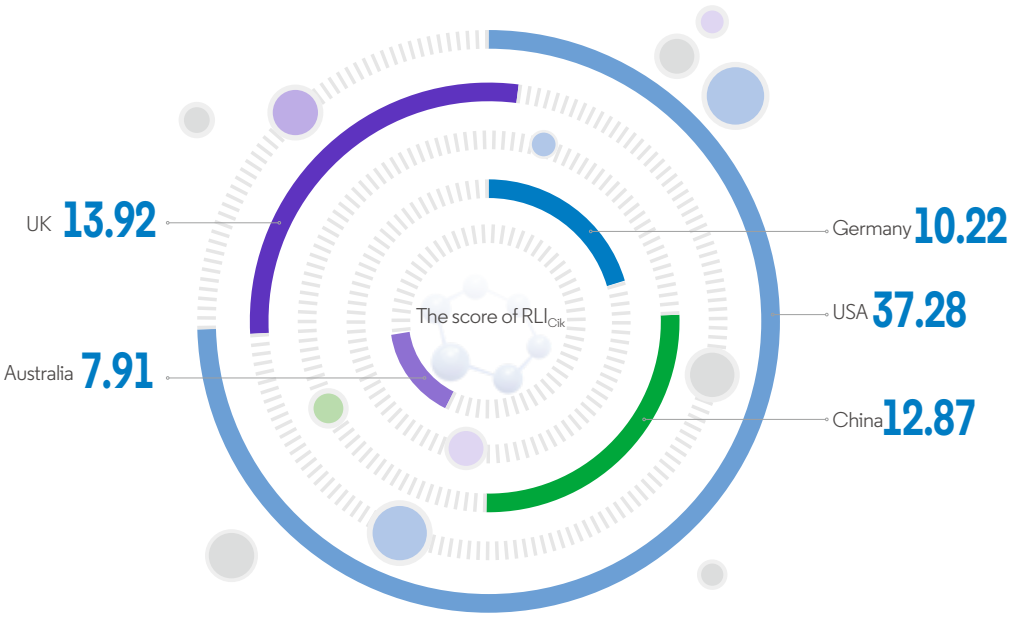


Table 10. The score and rank of Top 5 countries based on RLI_{Cik}, $RFOI_{Cik}$ and $RFII_{Cik}$ in the area of "Biological sciences"

Indicators	Score					Rank				
	USA	UK	China	Germany	Australia	USA	UK	China	Germany	Australia
RLI_{Cik}	37.28	13.92	12.87	10.22	7.91	1	2	3	4	5
$RFOI_{Cik}$	19.33	6.42	7.45	4.52	3.63	1	3	2	4	5
$RFII_{Cik}$	17.95	7.50	5.43	5.70	4.28	1	2	4	3	5

3.6 CHEMISTRY AND MATERIALS SCIENCE: China's RLI_{Cik} is 2.7 times as that of the USA; Singapore, Germany, and South Korea rank 3rd to 5th

In the area of "Chemistry and materials science", China's RLI_{Cik} score is 39.49, or 2.7 times that of the USA, earning China 1st place (Table 11). The USA scores 14.73, ranking 2nd. These scores indicate a significant activity gap between the USA and China. Compared with other countries, China and the USA are giants in this area. Singapore, Germany, and South Korea post marks of 3.72, 2.81, and 2.14 respectively, ranking 3rd to 5th. The rankings based on the indicators RLI_{Cik}, $RFOI_{Cik}$ and $RFII_{Cik}$ for the top five countries are exactly the same.

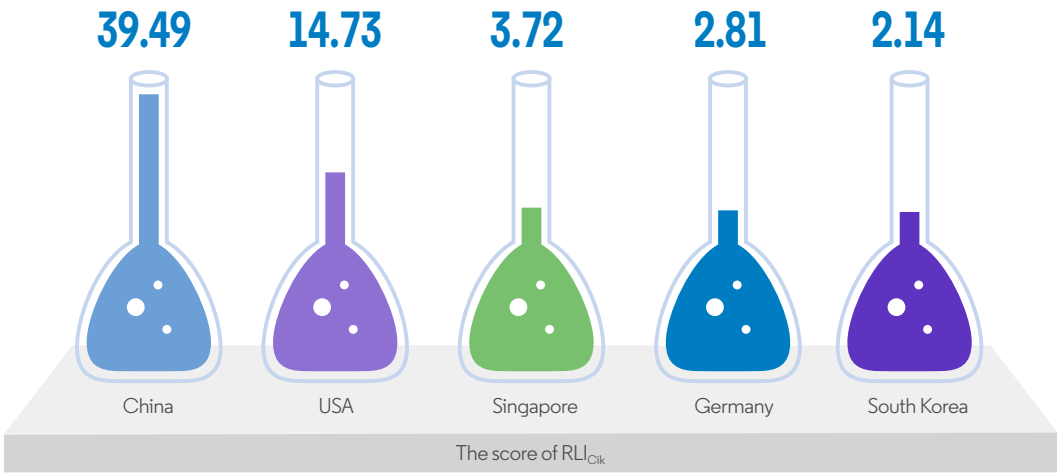


Table 11. The score and rank of Top 5 countries based on RLI_{Cik}, $RFOI_{Cik}$ and $RFII_{Cik}$ in the area of "Chemistry and materials science"

Indicators	Score					Rank				
	China	USA	Singapore	Germany	South Korea	China	USA	Singapore	Germany	South Korea
RLI_{Cik}	39.49	14.73	3.72	2.81	2.14	1	2	3	4	5
$RFOI_{Cik}$	23.01	7.14	1.97	1.40	1.18	1	2	3	4	5
$RFII_{Cik}$	16.48	7.59	1.75	1.41	0.96	1	2	3	4	5

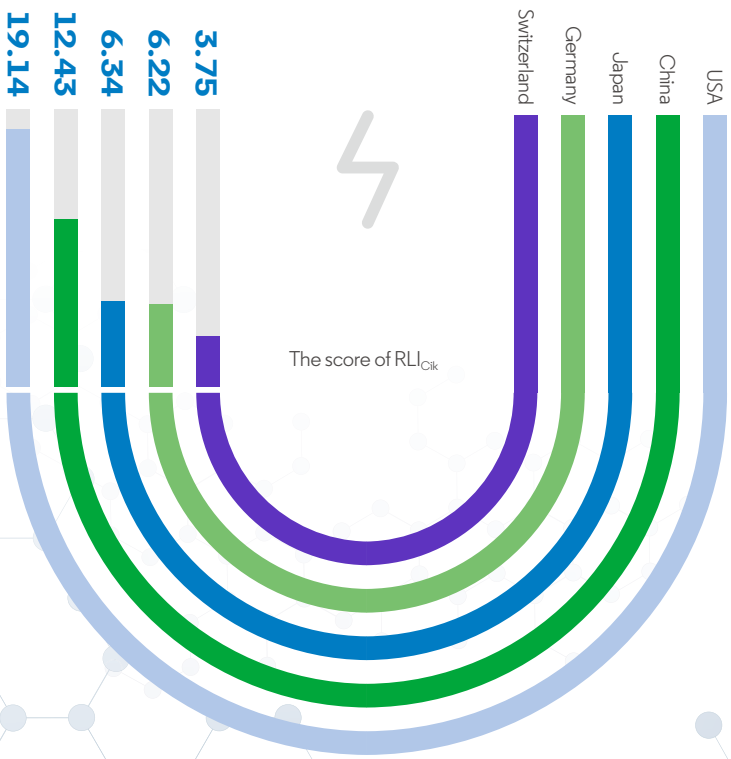
3.7 PHYSICS: The USA leads in all areas; China overtakes Japan for 2nd place; Germany and Switzerland are 4th and 5th

In the area of "Physics", the USA posts the highest degree of activity with an RLI_{Cik} of 19.14, showing an overall leading trend. China scores 12.43, while Japan and Germany score closely together at 6.34 and 6.22, respectively. Switzerland, in 5th place, scores 3.75, far behind the top four.

The USA, China, and Switzerland rank the same across all three indicators, while the rankings of the $RFOI_{Cik}$ indicator in Japan and Germany are inconsistent with the other two indicators.

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	Japan	Germany	Switzerland	USA	China	Japan	Germany	Switzerland
RLI_{Cik}	19.14	12.43	6.34	6.22	3.75	1	2	3	4	5
$RFOI_{Cik}$	10.12	8.05	3.35	3.58	1.93	1	2	4	3	5
$RFII_{Cik}$	9.01	4.38	2.99	2.64	1.81	1	2	3	4	5



3.8 ASTRONOMY AND ASTROPHYSICS: The USA has a dominant position; Germany, the UK, France, and Italy rank 2nd to 5th; and China ranks 8th

In the area of "Astronomy and astrophysics", the USA ranks 1st, with an RLI_{Cik} score of 23.23. Germany ranks 2nd with a mark of 14.95, with the UK 3rd at 12.35, followed by France (11.47) and Italy (9.58). China places 8th with a score of 6.80. Although China's performance is not outstanding, the country has made significant progress in the field, compared with last year's 11th and the year before last's 19th positions.

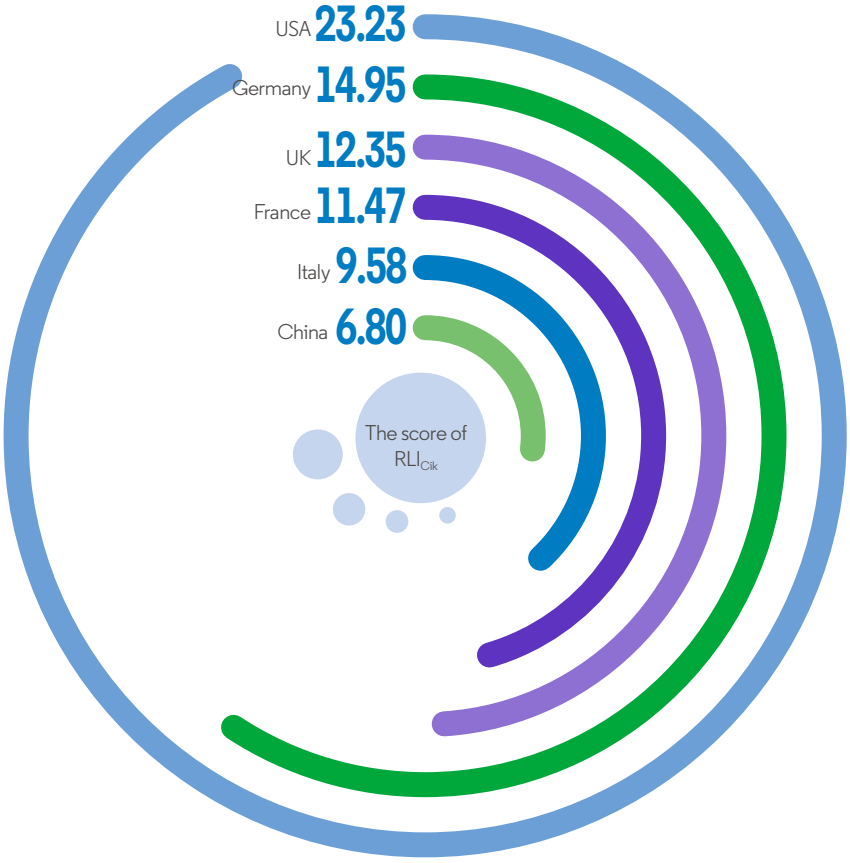


Table 13. The score and rank of Top 5 countries based on RLI_{Cik}, $RFOI_{Cik}$ and $RFII_{Cik}$ in the area of "Astronomy and astrophysics"

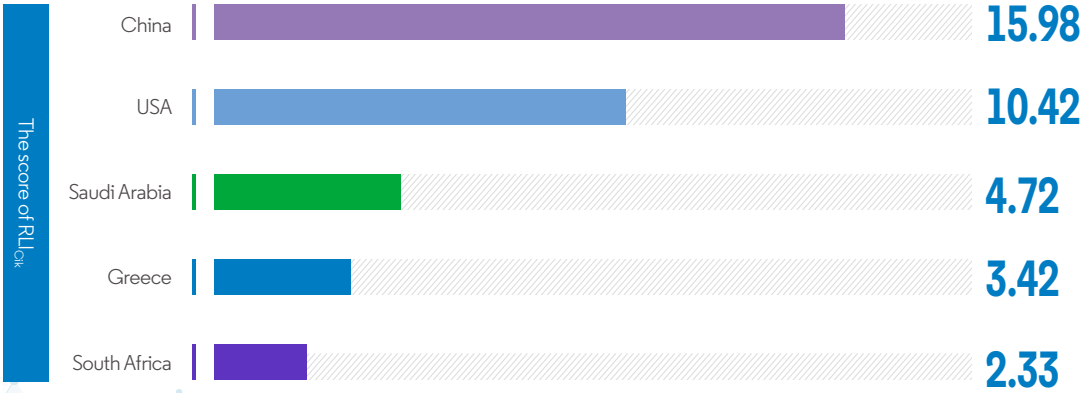
Indicators	Score						Rank					
	USA	Germany	UK	France	Italy	China	USA	Germany	UK	France	Italy	China
RLI_{Cik}	23.23	14.95	12.35	11.47	9.58	6.80	1	2	3	4	5	8
$RFOI_{Cik}$	13.24	7.74	6.50	5.81	4.78	3.39	1	2	3	4	5	8
$RFII_{Cik}$	9.99	7.22	5.85	5.65	4.80	3.40	1	2	3	4	6	8

3.9 MATHEMATICS: China is the most active, the USA is 2nd, while Saudi Arabia, Greece, and South Africa are 3rd to 5th

In the area of "Mathematics", China achieves the most active performance and ranks 1st, with a score of 15.98. Meanwhile, the USA posts a score of 10.42, ranking 2nd. Saudi Arabia, Greece, and South Africa score 4.72, 3.42 and 2.33 respectively, ranking 3rd to 5th. The rankings of the top 5 countries according to the three indicators are completely consistent.

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

Indicators	Score					Rank				
	China	USA	Saudi Arabia	Greece	South Africa	China	USA	Saudi Arabia	Greece	South Africa
RLI_{Cik}	15.98	10.42	4.72	3.42	2.33	1	2	3	4	5
$RFOI_{Cik}$	9.78	5.34	2.84	2.11	1.26	1	2	3	4	5
$RFII_{Cik}$	6.20	5.07	1.88	1.31	1.06	1	2	3	4	5



3.10 INFORMATION SCIENCE: China is the most active, while the USA is in the 2nd place; the UK, Canada and Singapore rank 3rd to 5th

In this area of "Information science", China demonstrates the highest level of activity, earning 1st place with an RLI_{Cik} score of 14.97. The USA posts a mark of 9.27, ranking 2nd. The UK, Canada and Singapore score 4.77, 3.83 and 2.67, ranking 3rd to 5th, respectively. The rankings based on the three indicators for the top five countries are exactly the same.

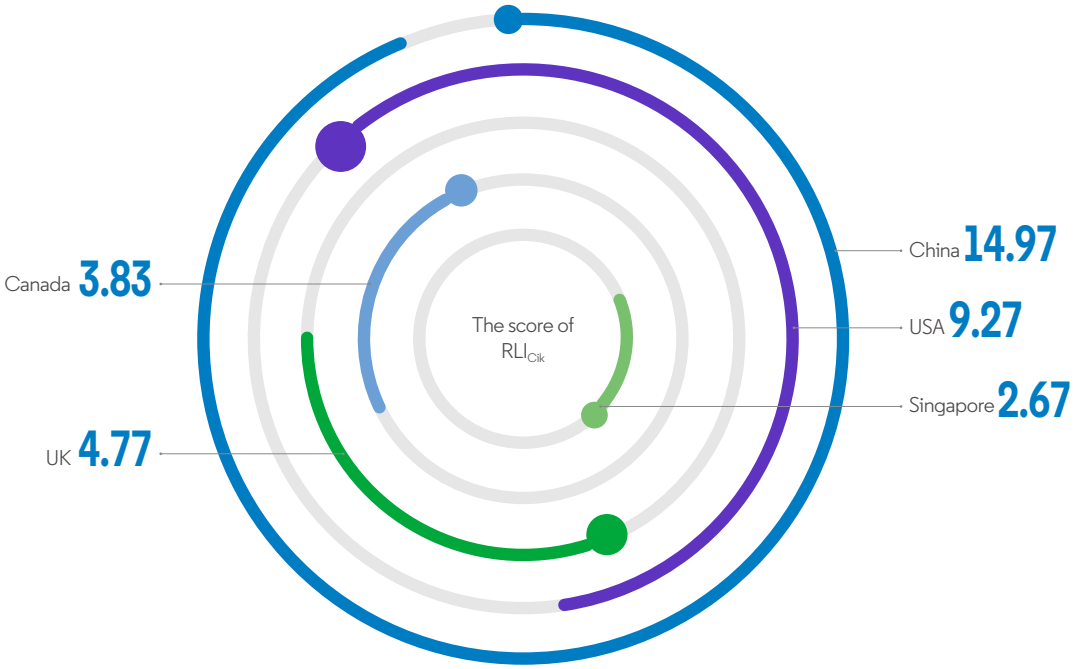


Table 15. The score and rank of Top 5 countries based on RLI_{Cik}, $RFOI_{Cik}$ and $RFII_{Cik}$ in the area of "Information science"

Indicators	Score					Rank				
	China	USA	UK	Canada	Singapore	China	USA	UK	Canada	Singapore
RLI_{Cik}	14.97	9.27	4.77	3.83	2.67	1	2	3	4	5
$RFOI_{Cik}$	9.32	4.92	2.51	1.74	1.40	1	2	3	4	5
$RFII_{Cik}$	5.64	4.35	2.27	2.09	1.27	1	2	3	4	5

3.11 ECONOMICS, PSYCHOLOGY AND OTHER SOCIAL SCIENCES: We find that the USA has advantages, while China is in 2nd place, rising steadily; the UK, Germany and Spain 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 13.27. China posts a mark of 9.03, ranking 2nd. The UK, Germany and Spain score 6.17, 4.15, and 3.26, ranking 3rd to 5th, respectively. The USA, China, the UK, and Germany rank exactly the same on the three indicators.

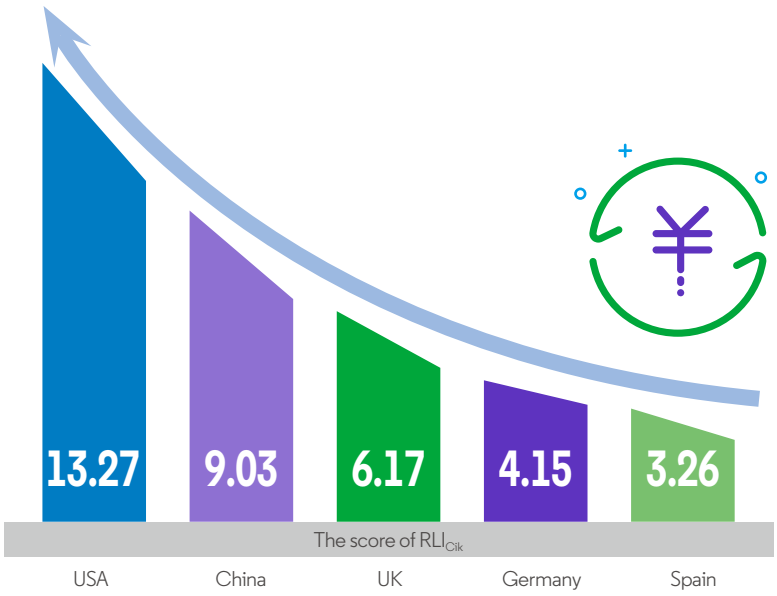


Table 16. The score and rank of Top 5 countries based on RLI_{Cik}, $RFOI_{Cik}$ and $RFII_{Cik}$ in the area of "Economics, psychology and other social sciences"

Indicators	Score					Rank				
	USA	China	UK	Germany	Spain	USA	China	UK	Germany	Spain
RLI_{Cik}	13.27	9.03	6.17	4.15	3.26	1	2	3	4	5
$RFOI_{Cik}$	7.28	5.40	3.79	2.17	1.93	1	2	3	4	5
$RFII_{Cik}$	5.99	3.63	2.38	1.98	1.33	1	2	3	4	6

Planner:
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