



中国科学院科技战略咨询研究院
Institutes of Science and Development, Chinese Academy of Sciences



2022

Research Fronts : Active Fields, Leading Countries

Institutes of Science and Development,
Chinese Academy of Sciences

Clarivate





2022 Research Fronts:
Active Fields, Leading Countries

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 2022” report is a prequel to another survey, “Research Fronts 2022: Active Fields, Leading Countries”, which selects and discusses 110 hot fronts and 55 emerging fronts in 11 broad research areas. Based on the findings of “Research Fronts 2022”, this 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.

110

Hot Research Fronts

55

Emerging Research Fronts

1. Methodology

1.1 The logic model of Research Leadership Index (RLI)

The Research Leadership Index (RLI) is a comprehensive evaluation measure to determine 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.

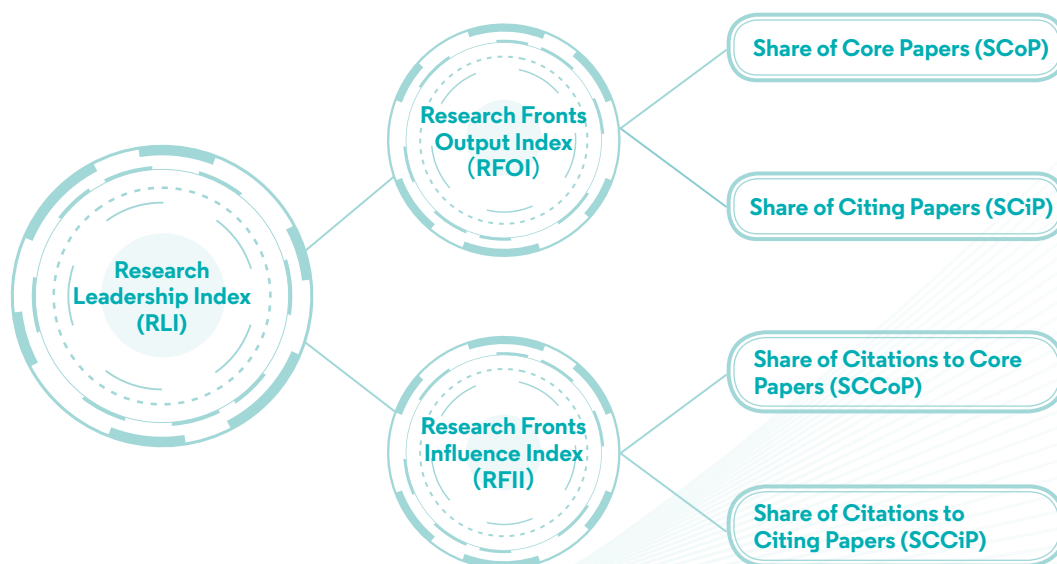


Figure 1. The logic model of Research Leadership Index (RLI)

The entities measured by the Research Leadership Index can be countries, cities, institutions, laboratories, teams, and individual scientists. Each entity 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 (RLIC)

This report calculates 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, the report 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 measures a country's degree of activity 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:

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

RFOI_{Cij} is the Research Fronts Output Index of a country, 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 the literature that constitutes 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 *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.

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

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

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

Country's Share of Core Paper Citation 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*.

The measure known as Country's Share of Citation to Citing Paper in a Research Front (SCCiP_{Cij}) indicates the percentage of in.

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

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:

$$RLI_{ik} = RFOI_{Cik} + RFII_{Cik} = \sum_{j=1}^n \frac{CoP_{ij}}{CoP_j} + \sum_{j=1}^n \frac{CiP_{ij}}{CiP_j} + \sum_{j=1}^n \frac{CoC_{ij}}{CoC_j} + \sum_{j=1}^n \frac{CiC_{ij}}{CiC_j}$$

RLI_{Cik} is 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 comprising n Research Fronts. $RFOI_{Cik}$ is equal to the sum of the two indicators $SCoP_{Cik}$ and $SCiP_{Cik}$.

$$RFOI_{Cik} = SCoP_{Cik} + SCiP_{Cik} = \sum_{j=1}^n \frac{CoP_{ij}}{CoP_j} + \sum_{j=1}^n \frac{CiP_{ij}}{CiP_j}$$

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

$$SCoP_{Cik} = \sum_{j=1}^n \frac{CoP_{ij}}{CoP_j}$$

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

$$SCiP_{Cik} = \sum_{j=1}^n \frac{CiP_{ij}}{CiP_j}$$

(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 comprising n Research Fronts. $RFII_{Cik}$ equals the sum of the two indicators $SCCoP_{Cik}$ and $SCCiP_{Cik}$.

$$RFII_{Cik} = SCCoP_{Cik} + SCCiP_{Cik} = \sum_{j=1}^n \frac{CoC_{ij}}{CoC_j} + \sum_{j=1}^n \frac{CiC_{ij}}{CiC_j}$$

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

$$SCCoP_{Cik} = \sum_{j=1}^n \frac{CoC_{ij}}{CoC_j}$$

Below, the formula for a country's Share of Citations to Citing Papers in an area ($SCCiP_{Cik}$):

$$SCCiP_{Cik} = \sum_{j=1}^n \frac{CiC_{ij}}{CiC_j}$$

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 evaluative index to measure the degree of activity of a country based on its contribution to 11 broad research areas comprising 165 Research Fronts.

$$RLI_{Ci} = RFOI_{Ci} + RFII_{Ci} = \sum_{k=1}^{10} \sum_{j=1}^n \frac{CoP_{ij}}{CoP_j} + \sum_{k=1}^{10} \sum_{j=1}^n \frac{CiP_{ij}}{CiP_j} + \sum_{k=1}^{10} \sum_{j=1}^n \frac{CoC_{ij}}{CoC_j} + \sum_{k=1}^{10} \sum_{j=1}^n \frac{CiC_{ij}}{CiC_j}$$

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 165 Research Fronts. $RFOI_{Ci}$ is equal to the sum of the two indicators $SCoP_{Ci}$ and $SCiP_{Ci}$.

$$RFOI_{Ci} = SCoP_{Ci} + SCiP_{Ci} = \sum_{k=1}^{10} \sum_{j=1}^n \frac{CoP_{ij}}{CoP_j} + \sum_{k=1}^{10} \sum_{j=1}^n \frac{CiP_{ij}}{CiP_j}$$

The formula for a country's Share of Core Papers in 11 broad research areas ($SCoP_{Ci}$) is as follows:

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

The formula for a country's Share of Citing Papers in 11 broad research areas ($SCiP_{Ci}$) is:

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



(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 165 Research Fronts. RFII_{ci} is equal to the sum of the two indicators SCCoP_{ci} and SCCiP_{ci}.

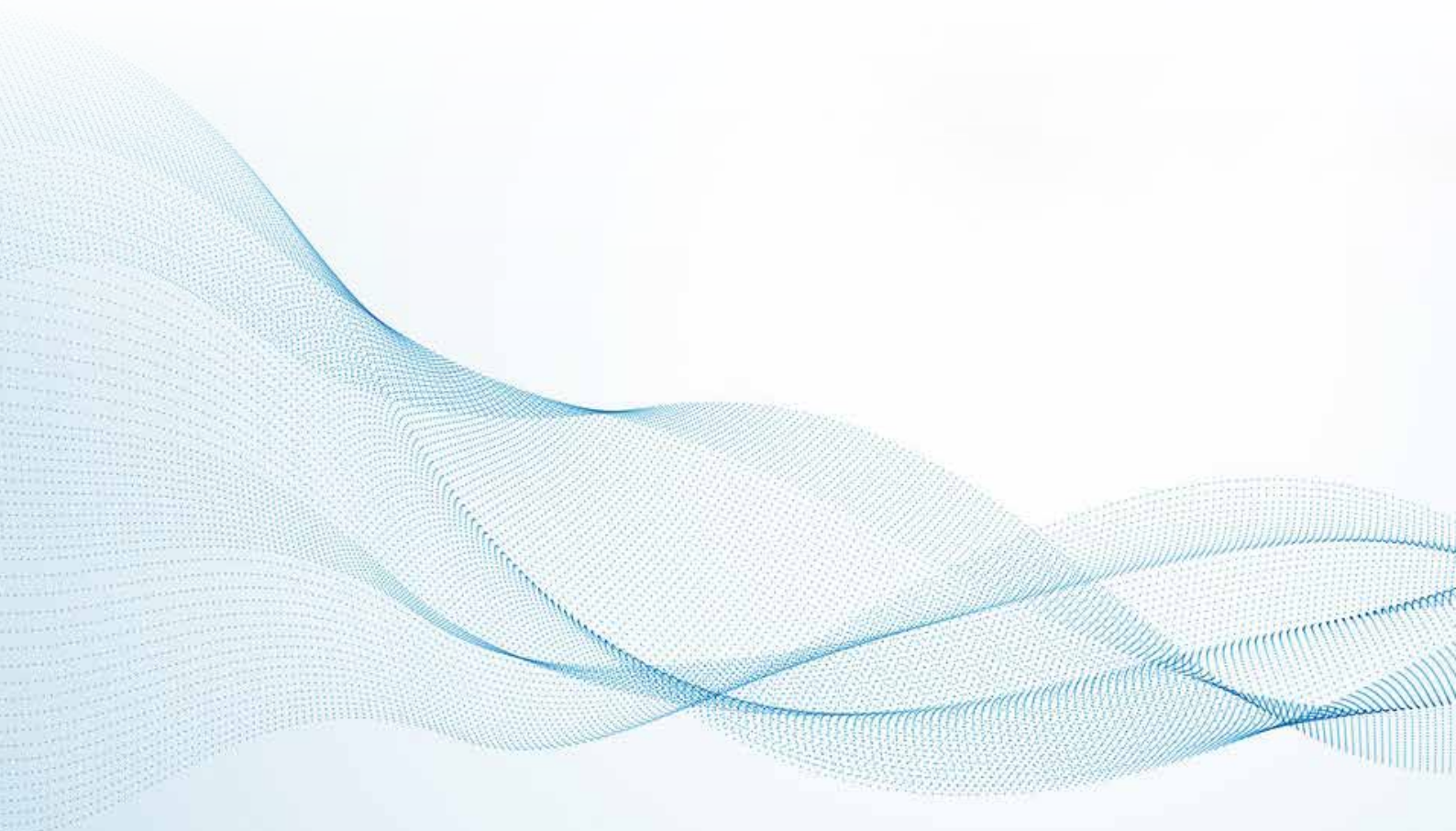
$$RFII_{ci} = SCCoP_{ci} + SCCiP_{ci} = \sum_{k=1}^{10} \sum_{j=1}^n \frac{CoC_{ij}}{CoC_j} + \sum_{k=1}^{10} \sum_{j=1}^n \frac{CiC_{ij}}{CiC_j}$$

The formula for a country's Share of Citations to Core Papers in 11 broad research areas (SCCoP_{ci}) is as follows:

$$SCCoP_{ci} = \sum_{k=1}^{10} \sum_{j=1}^n \frac{CoC_{ij}}{CoC_j}$$

The formula for a country's Share of Citations to Citing Papers in 11 broad research areas (SCCiP_{ci}) is:

$$SCCiP_{ci} = \sum_{k=1}^{10} \sum_{j=1}^n \frac{CiC_{ij}}{CiC_j}$$



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 165 Research Fronts and ranked the top countries. The following highlights are noted.



2.1 The USA ranks 1st in RLI_{Ci} , the two powerful nations of China¹ and the USA have solid positions, and the UK and Germany are in the second tier

Based on 11 broad research areas and each country's respective performance in the 165 constituent Research Fronts, the USA is the most active, with an RLI_{Ci} score of 194.89, ranking 1st (Figure 2). China ranks 2nd with a score of 148.34, and the gap with the USA is 46.55. Both China and the USA have a solid position, unmatched by any other countries. The UK and Germany score 85.11 and 65.65, respectively, ranking 3rd and 4th and occupying the second tier. France, which is in the 5th place, has a gap of at least 20 points with Germany.

The RLI_{Ci} scores for Italy, Australia, Spain, Canada, and Switzerland register between 41.05 and 28.86, ranking those nations from 6th to 10th, with Japan (at 28.25) ranking 11th.

¹ In this report, China covers Mainland China, Hong Kong, and Macau, but not Taiwan.

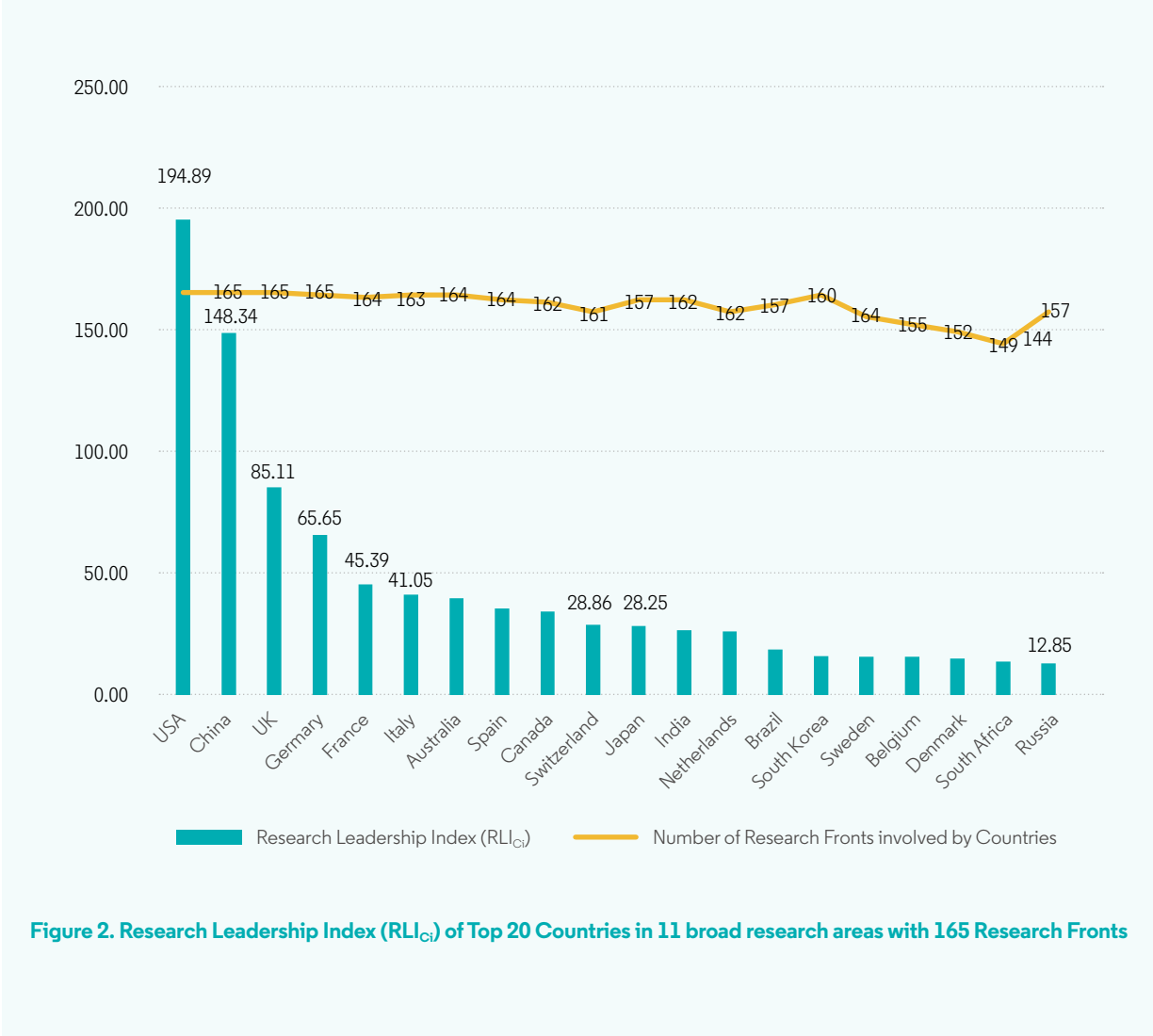


Figure 2. Research Leadership Index (RLI_{Ci}) of Top 20 Countries in 11 broad research areas with 165 Research Fronts

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.

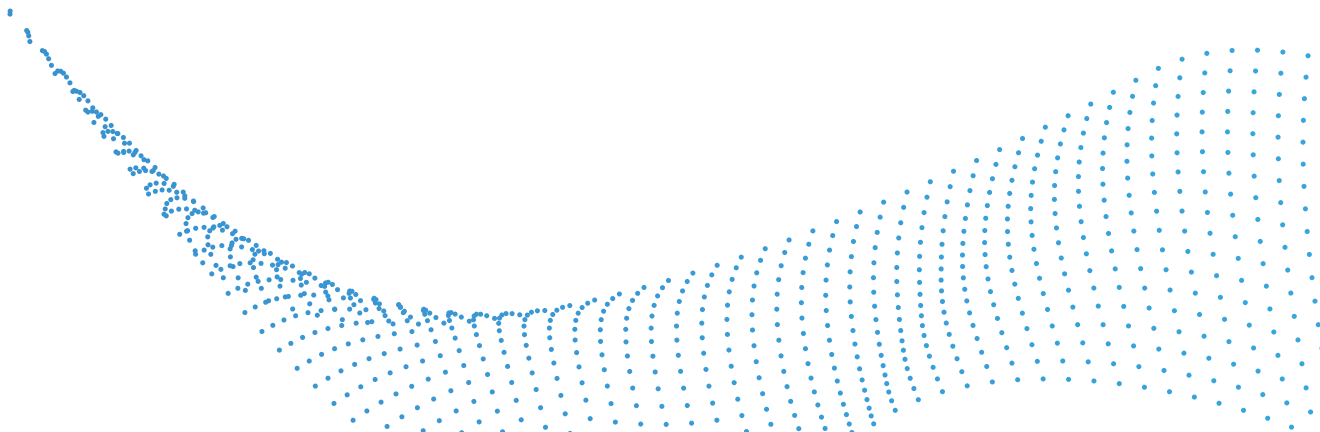


Table 1. The Research Leadership Index (RLI_{Ci}) of Top 20 Countries in 11 broad research areas with 165 Research Fronts

	RLI _{Ci}		RFOI _{Ci}		RFII _{Ci}	
	Score	Rank	Score	Score	Rank	Score
USA	194.89	1	116.37	1	78.52	1
China	148.34	2	95.07	2	53.27	2
UK	85.11	3	48.87	3	36.24	3
Germany	65.65	4	38.30	4	27.35	4
France	45.39	5	26.00	5	19.39	5
Italy	41.05	6	24.81	6	16.24	7
Australia	39.60	7	23.34	7	16.26	6
Spain	35.54	8	21.07	8	14.47	8
Canada	34.31	9	20.34	9	13.97	9
Switzerland	28.86	10	16.31	12	12.55	10
Japan	28.25	11	17.12	11	11.13	12
India	26.50	12	18.47	10	8.03	13
Netherlands	26.16	13	14.20	13	11.96	11
Brazil	18.57	14	11.30	14	7.27	15
South Korea	15.85	15	9.74	15	6.11	18
Sweden	15.68	16	8.92	16	6.76	16
Belgium	15.62	17	8.35	17	7.27	14
Denmark	15.02	18	8.27	18	6.75	17
South Africa	13.63	19	7.64	19	5.99	19
Russia	12.85	20	7.44	20	5.41	20

Table 2 compares the Research Leadership Index (RLI_{Ci}) of the USA, China, the UK, Germany, and France in 2017, 2018, 2019, 2020, 2021, and 2022, and the proportion relative to the USA. From 2017 to 2020, the above five countries consistently ranked among the top five.

The USA scores 281.11, 227.39, 204.89, 226.63, 209.23, and 194.89, respectively in the six years, maintaining 1st place. China ranks 2nd with 118.84, 118.38, 139.68, 151.29, 191.43,

In 2022, the ratio of China to the USA drops to 76.12%. Although China’s score declined compared with 2021, it still increased by nearly 10% compared with the ratio in 2020.

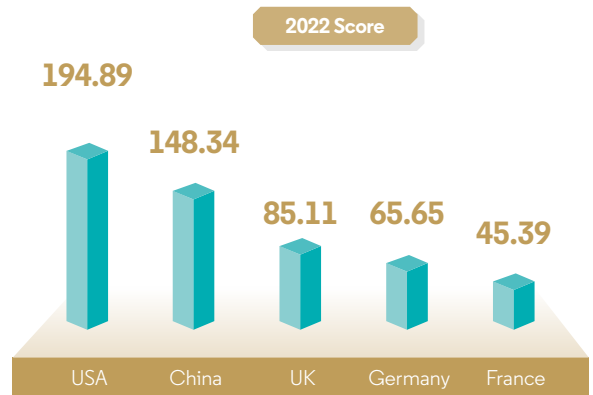
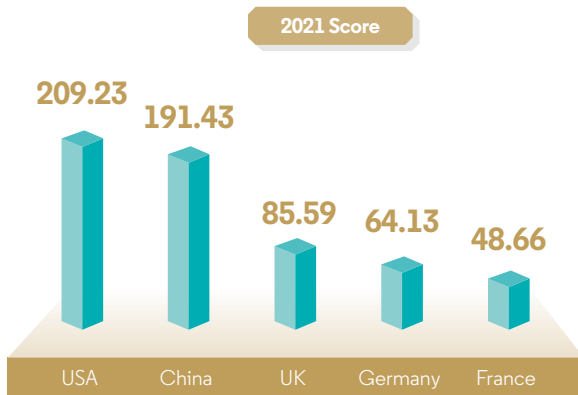
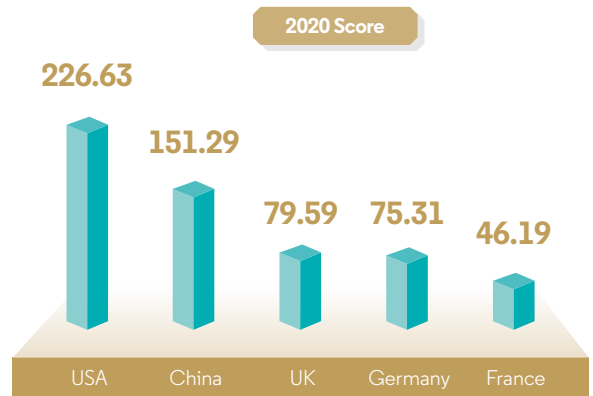
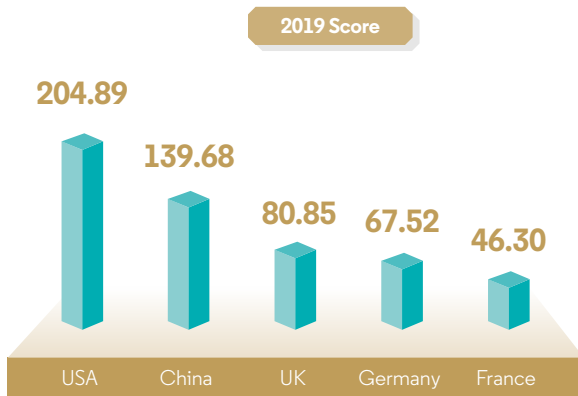
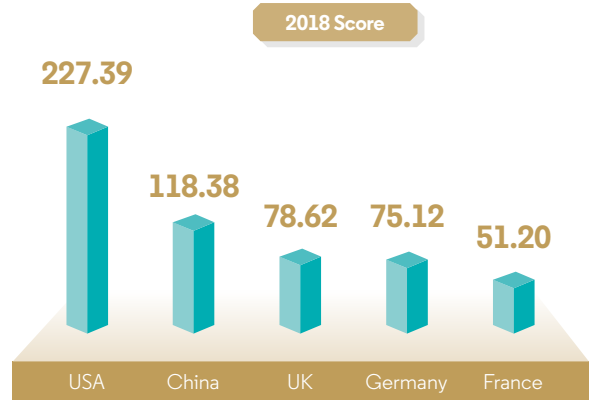
Meanwhile, the UK and Germany rank 3rd and 4th for six years,

and 148.34 points in six 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%, 68.18%, 66.76%, 91.50%, and 76.11% for the six years. Thus, the proportion of China to the USA has increased significantly, especially in 2021, reaching 91.50% (a rise related to the surge of research on the COVID-19 epidemic).

with little change compared with the USA. France ranks 5th from 2017 to 2020. However, in 2021, France fell to 6th and Italy won 5th. France returned to the 5th place in 2022.

Table 2. Research Leadership Index (RLI_{Ci}) for Top 20 Countries in 11 broad research areas with 165 Research Fronts, for each of five years, 2017 to 2022

Indicators	Year	USA	China	UK	Germany	France
Research Leadership Index (RLI _{Ci}) Score	2017	281.11	118.84	96.90	90.98	60.08
	2018	227.39	118.38	78.62	75.12	51.20
	2019	204.89	139.68	80.85	67.52	46.30
	2020	226.63	151.29	79.59	75.31	46.19
	2021	209.23	191.43	85.59	64.13	48.66
	2022	194.89	148.34	85.11	65.65	45.39
%	2017	100.00%	42.28%	34.47%	32.36%	21.37%
	2018	100.00%	52.06%	34.57%	33.04%	22.52%
	2019	100.00%	68.18%	39.46%	32.95%	22.60%
	2020	100.00%	66.76%	34.95%	33.07%	20.29%
	2021	100.00%	91.50%	40.91%	30.65%	23.26%
	2022	100.00%	76.12%	43.67%	33.68%	23.29%





2.2 The USA shows obvious strength in leading seven areas, while China has outstanding performance in four areas

For the 11 broad research areas, the USA's RLI_{Ci} scores are 1st in seven of the main areas: "Geosciences", "Clinical medicine", "Biological sciences", "Astronomy and astrophysics", "Mathematics", "Information science", and "Economics, psychology and other social sciences", and 2nd in the other four areas. The figures indicate that, overall, the USA is exceptionally active in basic research.

China's RLI_{Ci} scores ranks 1st in four areas "Agricultural, plant and animal sciences", "Ecology and environmental sciences", "Chemistry and materials science", and "Physics". China ranks 2nd in five areas: "Geosciences", "Biological sciences", "Mathematics", "Information science", and "Economics, psychology and other social sciences", while ranks 7th in "Astronomy and astrophysics".

"Clinical medicine" and "Astronomy and astrophysics" have always been relatively weak areas for China. From a historical perspective, we compare the changes of RLI_{Ci} in these two areas in the last six years. From 2017 to 2022, China ranked 10th, 13th, 9th, 12th, 1st, and 4th in terms of RLI_{Ci} in the area of "Clinical medicine", in which the research on COVID-19 in 2021 and 2022 accounted for a large proportion, directly elevating China's ranking in the area of "Clinical medicine". However, whether China's non COVID-19-related research in "Clinical medicine" has truly made significant progress needs further analysis. China ranked 11th, 19th, 11th, 8th, 8th, and 7th respectively in "Astronomy and astrophysics" for the last six years, from 11th in 2017 to 7th in 2022. Although, compared with other areas, China's ranking in this area is still relatively low, the nation's significant progress is obvious.

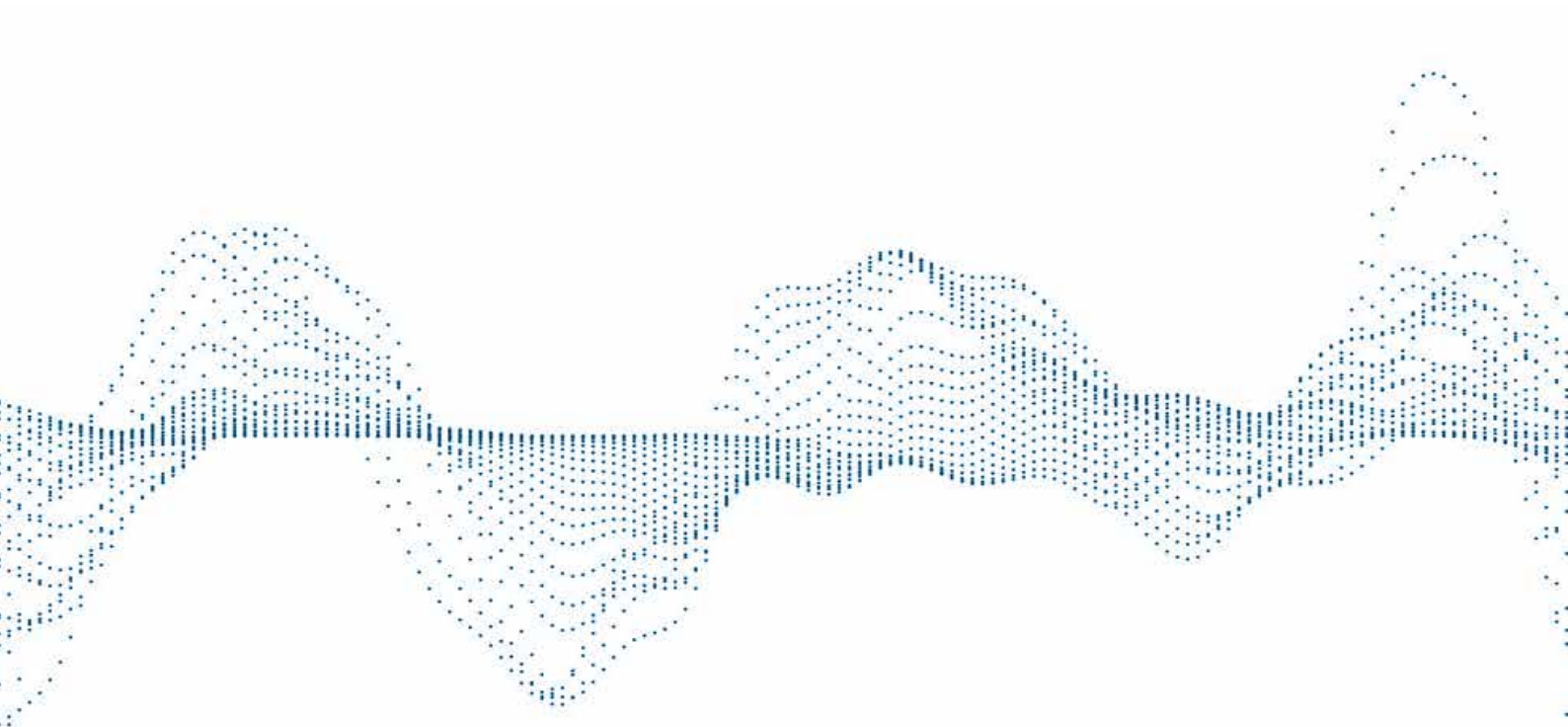


Table 3. The score and rank of RLI_{Cj} and RLI_{Cjk} of Top20 Countries

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	194.89	1	8.67	2	7.17	2	16.02	1	39.14	1	25.67	1	9.57	2	12.74	2	24.64	1	23.03	1	11.28	1	16.96	1
China	148.34	2	15.55	1	14.32	1	10.28	2	10.45	4	20.23	2	23.82	1	14.80	1	7.00	7	8.16	2	9.59	2	14.13	2
UK	85.11	3	2.27	7	4.95	4	9.17	3	16.30	2	13.61	3	1.83	6	4.99	5	11.19	3	5.00	4	5.90	3	9.88	3
Germany	65.65	4	2.51	6	3.70	5	5.62	5	11.42	3	8.49	4	2.09	3	6.67	3	13.40	2	5.75	3	1.86	9	4.13	7
France	45.39	5	1.81	10	1.69	12	6.66	4	8.25	6	3.22	10	0.77	13	2.45	11	9.98	4	2.67	6	3.26	6	4.64	6
Italy	41.05	6	2.02	9	1.57	13	3.29	10	9.89	5	4.13	7	0.91	11	3.95	6	7.62	5	1.47	9	2.09	8	4.11	8
Australia	39.60	7	3.21	4	6.25	3	5.49	6	3.65	14	5.28	5	1.63	7	0.42	36	5.28	10	1.72	7	1.18	11	5.50	5
Spain	35.54	8	5.18	3	2.08	11	2.11	17	7.92	7	1.27	20	0.37	22	3.31	8	6.14	8	1.58	8	2.46	7	3.12	11
Canada	34.31	9	1.53	12	2.94	6	4.93	7	5.82	9	1.90	15	1.24	9	2.61	10	4.85	11	0.69	18	3.89	4	3.92	9
Switzerland	28.86	10	0.52	27	1.20	14	3.56	9	5.26	11	3.29	8	1.41	8	2.82	9	5.47	9	3.04	5	0.74	15	1.57	22
Japan	28.25	11	0.99	17	1.00	17	4.91	8	3.38	15	1.54	17	1.84	5	6.25	4	4.61	12	1.36	10	0.46	24	1.91	18
India	26.50	12	3.15	5	2.26	8	2.07	18	2.91	17	4.25	6	0.76	14	1.62	14	2.61	19	0.30	21	0.62	20	5.95	4
Netherlands	26.16	13	0.92	20	2.57	7	2.94	11	3.79	13	2.84	13	0.09	35	0.62	24	7.56	6	0.88	16	0.57	21	3.38	10
Brazil	18.57	14	1.69	11	2.17	10	0.20	35	5.33	10	3.19	11	0.15	30	1.07	16	3.16	15	0.25	24	0.18	35	1.17	30
South Korea	15.85	15	1.40	13	0.42	31	1.53	21	1.17	27	2.77	14	1.97	4	1.56	15	2.02	23	0.33	20	1.64	10	1.03	35
Sweden	15.68	16	0.31	39	0.85	19	2.30	14	1.86	19	1.49	18	0.68	15	1.88	12	3.24	14	0.36	19	1.06	12	1.66	20
Belgium	15.62	17	0.99	18	0.67	24	1.14	24	3.15	16	3.25	9	0.45	18	0.81	21	3.09	16	1.13	12	0.19	34	0.76	41
Denmark	15.02	18	0.22	43	0.35	36	2.44	12	5.84	8	1.84	16	0.06	39	0.53	29	2.48	20	0.09	37	0.20	33	0.97	37
South Africa	13.63	19	0.58	23	0.81	21	0.40	31	3.82	12	3.01	12	0.04	44	0.28	39	1.59	30	0.02	56	0.03	52	3.05	12
Russia	12.85	20	0.22	42	0.39	33	1.79	19	0.68	39	0.97	23	0.24	25	3.75	7	2.15	21	0.91	14	0.68	18	1.06	34

Among the 110 hot Research Fronts and 55 emerging Research Fronts in 11 broad research areas, the USA ranks 1st in 79, accounting for 47.88% of the 165 Research Fronts. China earns the top spot in 52 fronts, or 31.52%. The UK is tops in eight Research Fronts, Germany ranks 1st in five, while France can claim the top ranking in one front (Table 4). The USA and China account for about 79.39% of the 165 fronts while the UK and Germany together account for about 7.88%, while the other 12.73% is shared by 14 countries.

Of the 11 broad research areas, there are 10 fronts within “Chemistry and materials science” and eight fronts within “Ecology and environmental sciences” in which China ranks 1st, compared to only two and one, respectively, for the USA. China is showing absolute advantage in the area of “Chemistry and materials science” and is also demonstrating

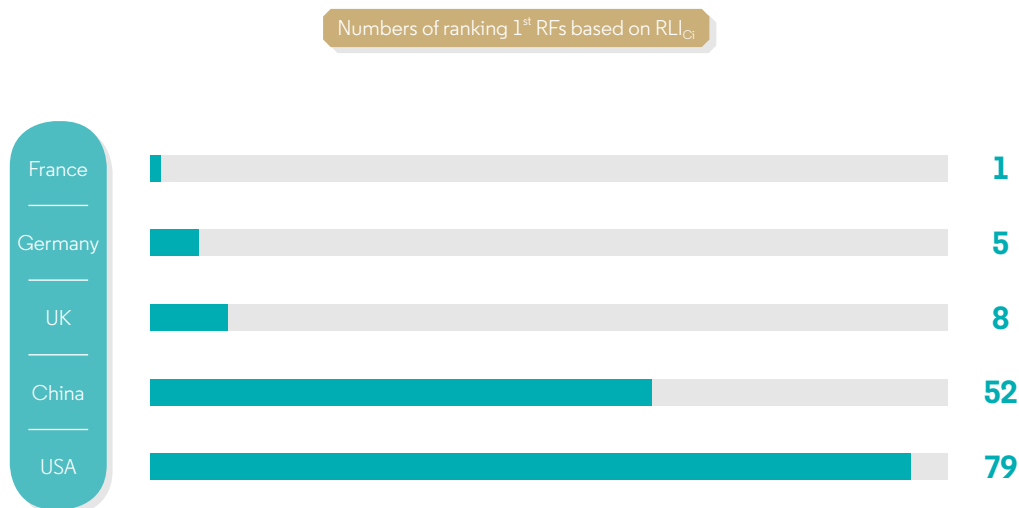
rising advantage in the area of “Ecology and environmental sciences”.

In the areas of “Agricultural, plant and animal sciences” and “Physics”, the number of fronts in which China ranks 1st is six, while that of the USA is four. In the five areas of “Geosciences”, “Biological sciences”, “Mathematics”, “Information science”, and “Economics, psychology and other social sciences”, the number of fronts in which China ranks 1st is less than that of the USA.

Among the 27 fronts in “Clinical medicine”, the USA ranks 1st in 20, while China leads in only three fronts, indicating a huge gap between China and the USA in the index. Among the 12 fronts in the area of “Astronomy and astrophysics”, the USA ranks 1st in 11 fronts, while China has none (Table 4). This relative gap is unlikely to narrow in the short term.

Table 4. The numbers and ratios of the Research Fronts in which the respective Top 5 countries rank first, out of 165 fronts in 11 broad research areas (based on RLI_{Ci})

Areas	Numbers of RFs	Numbers of ranking 1 st RFs					Ratios				
		USA	China	UK	Germany	France	USA	China	UK	Germany	France
11 broad research areas total	165	79	52	8	5	1	47.88%	31.52%	4.85%	3.03%	0.61%
Agricultural, plant and animal sciences	12	4	6	0	0	0	33.33%	50.00%	0.00%	0.00%	0.00%
Ecology and environmental sciences	12	1	8	0	1	0	8.33%	66.67%	0.00%	8.33%	0.00%
Geosciences	11	6	2	1	0	0	54.55%	18.18%	9.09%	0.00%	0.00%
Clinical medicine	27	20	3	2	1	0	74.07%	11.11%	7.41%	3.70%	0.00%
Biological sciences	21	10	6	2	0	0	47.62%	28.57%	9.52%	0.00%	0.00%
Chemistry and materials science	13	2	10	0	0	0	15.38%	76.92%	0.00%	0.00%	0.00%
Physics	12	4	6	0	0	0	33.33%	50.00%	0.00%	0.00%	0.00%
Astronomy and astrophysics	12	11	0	0	1	0	91.67%	0.00%	0.00%	8.33%	0.00%
Mathematics	12	8	2	0	1	0	66.67%	16.67%	0.00%	8.33%	0.00%
Information science	12	5	4	1	0	0	41.67%	33.33%	8.33%	0.00%	0.00%
Economics, psychology and other social sciences	21	8	5	2	1	1	38.10%	23.81%	9.52%	4.76%	4.76%



Among countries ranking among the top three performers in the 165 Research Fronts (Table 5), the USA earns that distinction in 130 fronts, or 78.79%, China in 86 Research Fronts (52.12%), the UK in 58, Germany in 37, and France

in 18, with the latter three countries able to boast the achievement in 35.15%, 22.42%, and 10.91% of the total number of Research Fronts.

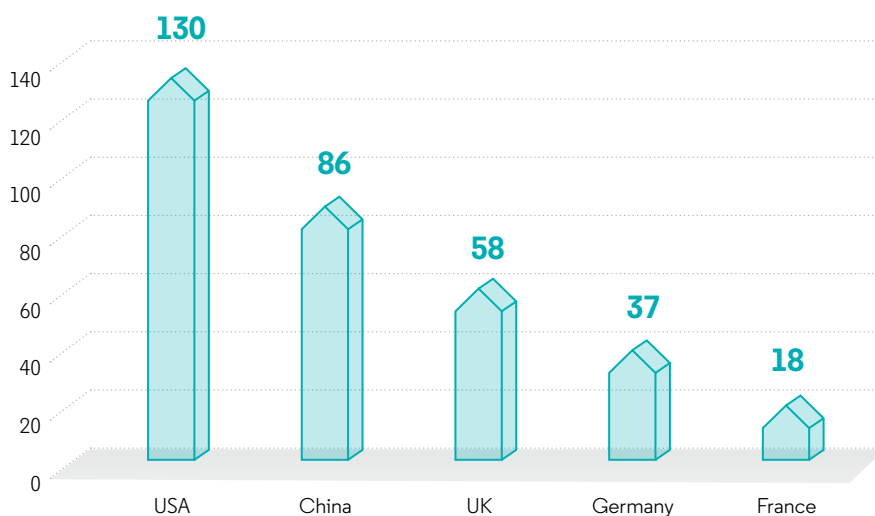
Table 5. The numbers and ratios of nations ranking among the top three performers in Research Fronts, among the Top 5 countries in 11 broad research areas with 165 Research Fronts (based on RLI_{Ci})

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	165	130	86	58	37	18	78.79%	52.12%	35.15%	22.42%	10.91%
Agricultural, plant and animal sciences	12	6	11	2	0	0	50.00%	91.67%	16.67%	0.00%	0.00%
Ecology and environmental sciences	12	6	8	4	2	0	50.00%	66.67%	33.33%	16.67%	0.00%
Geosciences	11	9	4	4	3	2	81.82%	36.36%	36.36%	27.27%	18.18%
Clinical medicine	27	25	9	12	7	5	92.59%	33.33%	44.44%	25.93%	18.52%
Biological sciences	21	18	12	9	6	0	85.71%	57.14%	42.86%	28.57%	0.00%
Chemistry and materials science	13	10	12	2	2	0	76.92%	92.31%	15.38%	15.38%	0.00%
Physics	12	8	7	2	4	1	66.67%	58.33%	16.67%	33.33%	8.33%
Astronomy and astrophysics	12	12	1	5	7	2	100.00%	8.33%	41.67%	58.33%	16.67%



Areas	Numbers of RFs	Numbers of ranking Top three RFs					Ratios				
		USA	China	UK	Germany	France	USA	China	UK	Germany	France
Mathematics	12	12	6	4	3	1	100.00%	50.00%	33.33%	25.00%	8.33%
Information science	12	10	8	5	1	3	83.33%	66.67%	41.67%	8.33%	25.00%
Economics, psychology and other social sciences	21	14	8	9	2	4	66.67%	38.10%	42.86%	9.52%	19.05%

Numbers of ranking Top three RFs



The USA makes the top three in more than 50% of the respective Research Fronts associated with each of the 11 broad research areas. In the two areas of “Astronomy and astrophysics” and “Mathematics”, 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”, in which the USA ranks among the top three in 92.59%. The lowest proportion for the USA is in the two areas of “Agricultural, plant and animal sciences” and “Ecology and environmental sciences”, accounting for 50%.

In the other five areas, meanwhile, the USA’s proportions of top three account range from 66.67% to 85.71%.

China’s proportion of top-three placements ratio reaches more than 50% in seven major specialty areas, of which the highest proportion is in “Chemistry and material science” and “Agricultural, plant and animal sciences”, accounting for 92.31% and 91.67%. China registers among the top three in the range of 66.67% in “Information science” and “Ecology and environmental sciences”. In the area of “Biological sciences” and “Physics”, the proportion of top-three placements ratio register at 57.14% and 58.33%. In the

area of “Mathematics”, the China’s presence in the top three accounts for 50% of Research Fronts, which is the closest to the average level of 52.12% in all areas.

China’s ratio of top three fronts in the three areas of “Geosciences”, “Clinical medicine”, and “Economics,

psychology and other social sciences” is 36.36%, 33.33%, and 38.10%. China’s proportion of top three placements in “Astronomy and astrophysics” is 8.33%. However, compared with the gap in this indicator in 2021 and before, China has achieved breakthrough.

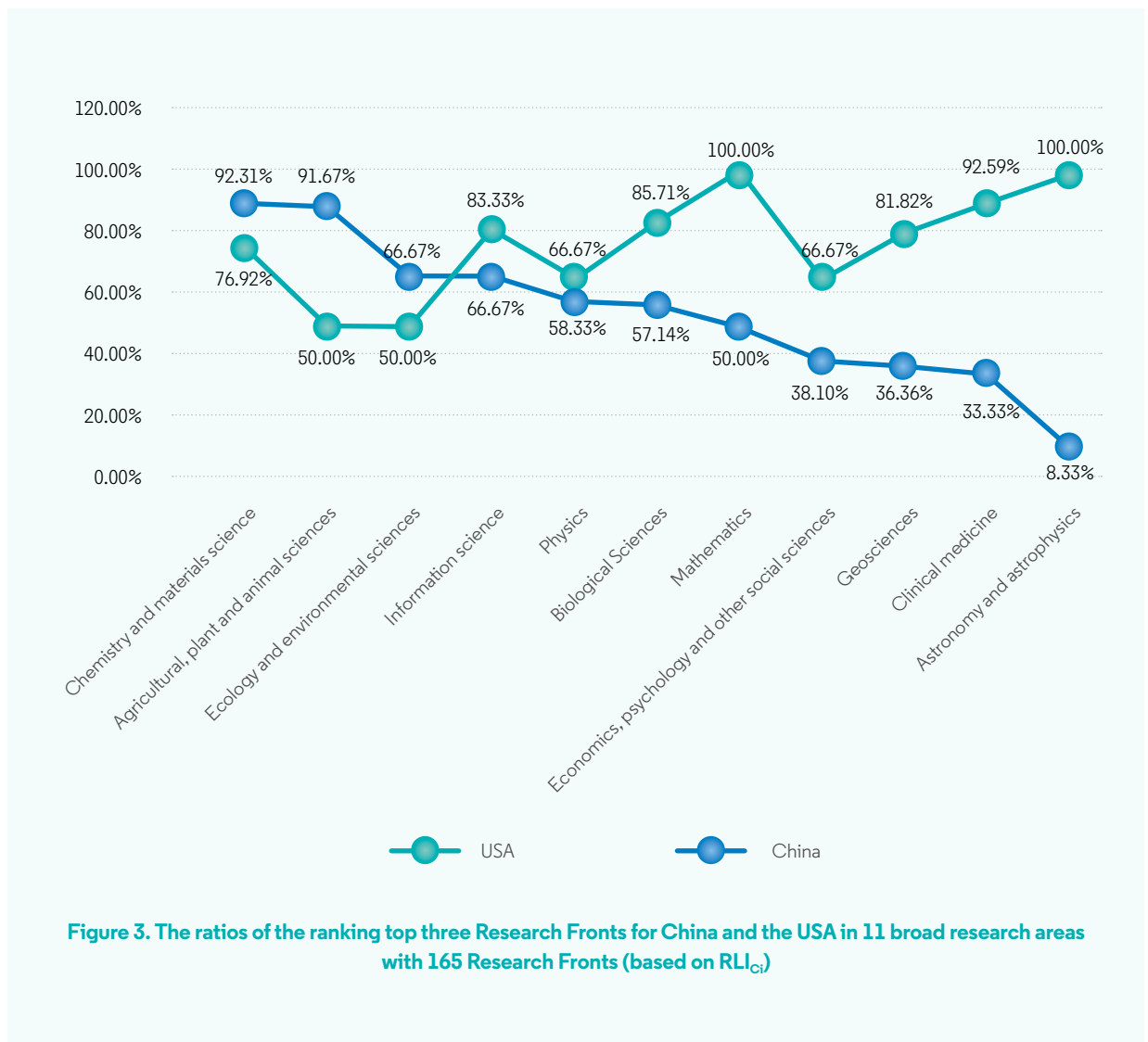
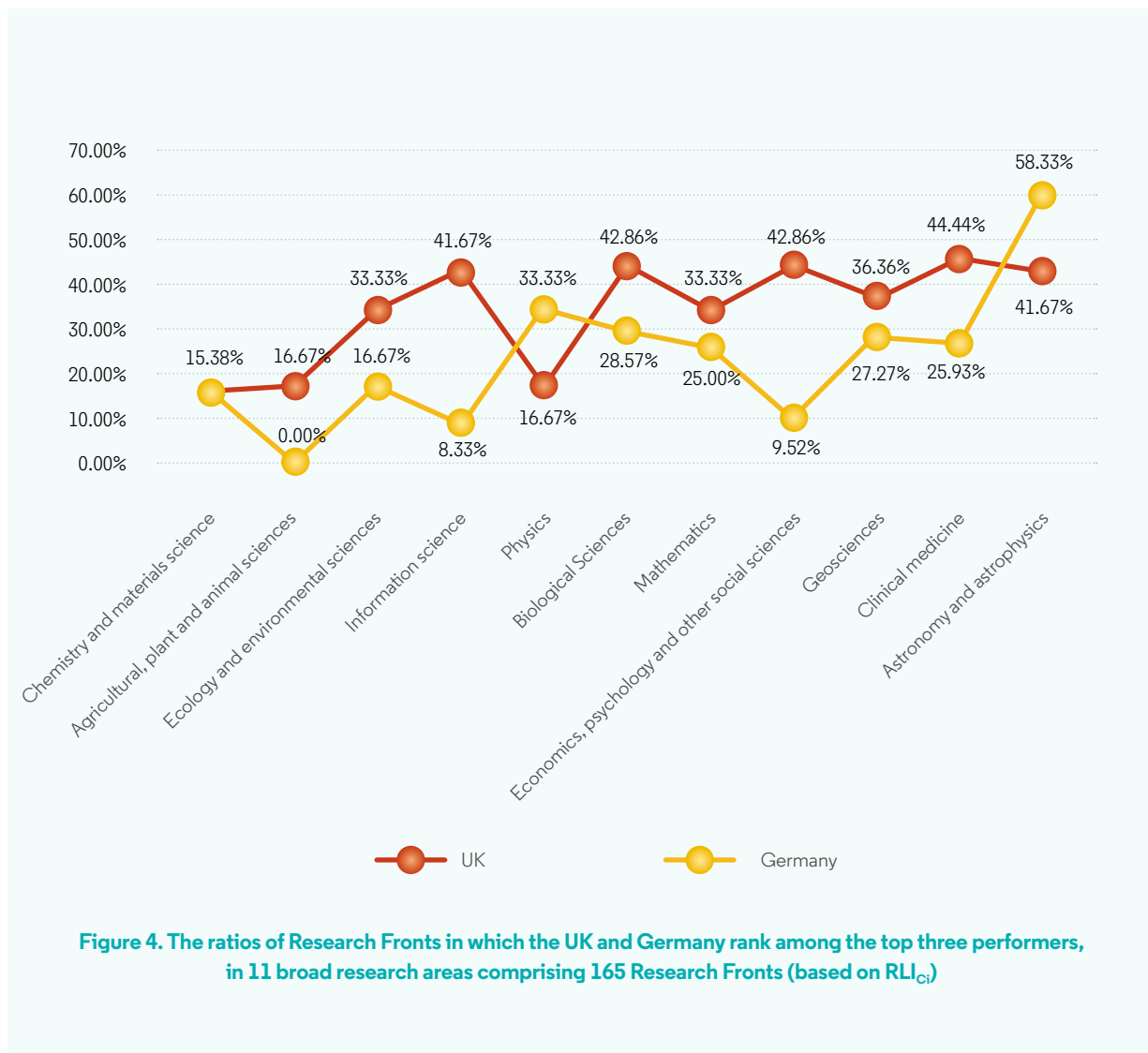


Figure 3. The ratios of the ranking top three Research Fronts for China and the USA in 11 broad research areas with 165 Research Fronts (based on RLI_{Ci})



The percentage of UK's top three Research Fronts in the 11 areas are all below 50%, registering among the top three by proportions ranging from 15.38% and 16.67% of the Research Fronts in three broad specialty areas: "Agricultural, plant and animal sciences", "Chemistry and materials science", and "Physics". In the other eight areas, the UK's presence in the top three ranges from 33.33% to 44.44% of Research Fronts.

Germany has its highest proportion of top three Research Fronts in the area of "Astronomy and astrophysics", accounting for 58.33%, representing the nation's dominant performance. Germany ranks in the top three no more than 33.33% of Research Fronts in the other ten areas. Among them, Germany, does not rank in the top three in the area of "Agricultural, plant and animal sciences".



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 has an obvious advantage; the USA is 2nd; Spain, Australia, and India 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 15.55, ranking 1st (Table 6). The USA scores 8.67, ranking 2nd. Spain scores 5.18, ranking 3rd. Australia and India post scores close to each other, ranking 4th and 5th, respectively. As can be seen from Table 6, the ranking according to RFI_{Cik} and $RFOI_{Cik}$ is the same as RLI_{Cik} for China, the USA and Spain. By contrast, the rankings for Spain, Australia and India vary slightly according to the three indicators.

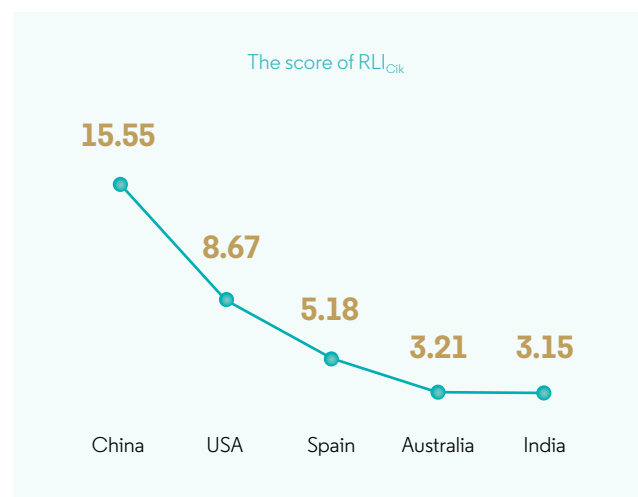




Table 6. The score and rank of the Top 5 countries based on RLI_{Cik} , $RFOI_{Cik}$ and $RFII_{Cik}$ in the area of “Agricultural, plant and animal sciences”

Indicators	Score					Rank				
	China	USA	Spain	Australia	India	China	USA	Spain	Australia	India
RLI_{Cik}	15.55	8.67	5.18	3.21	3.15	1	2	3	4	5
$RFOI_{Cik}$	9.81	5.38	2.94	1.91	2.19	1	2	3	5	4
$RFII_{Cik}$	5.74	3.29	2.24	1.30	0.96	1	2	3	4	7

3.2 ECOLOGY AND ENVIRONMENTAL SCIENCES: China leads; the USA is 2nd; Australia, the UK, and Germany rank 3rd, 4th, and 5th

In the area of “Ecology and environmental sciences” (Table 7), China scores 14.32 in RLI_{Cik} , ranking 1st, demonstrating the most activity. The USA scores 7.17, ranking 2nd.

China’s score is about twice that of the USA, with a leading position. Australia scores 6.25, ranking 3rd. The UK and Germany are in 4th and 5th place, with respective scores of 4.95

and 3.70.

The rank order of China, the UK, and Germany remains the same for all three indicators: RLI_{Cik} , $RFOI_{Cik}$ and $RFII_{Cik}$. Meanwhile, the rankings of the $RFOI_{Cik}$ indicator for the USA and Australia fluctuate somewhat compared to the other two measures.

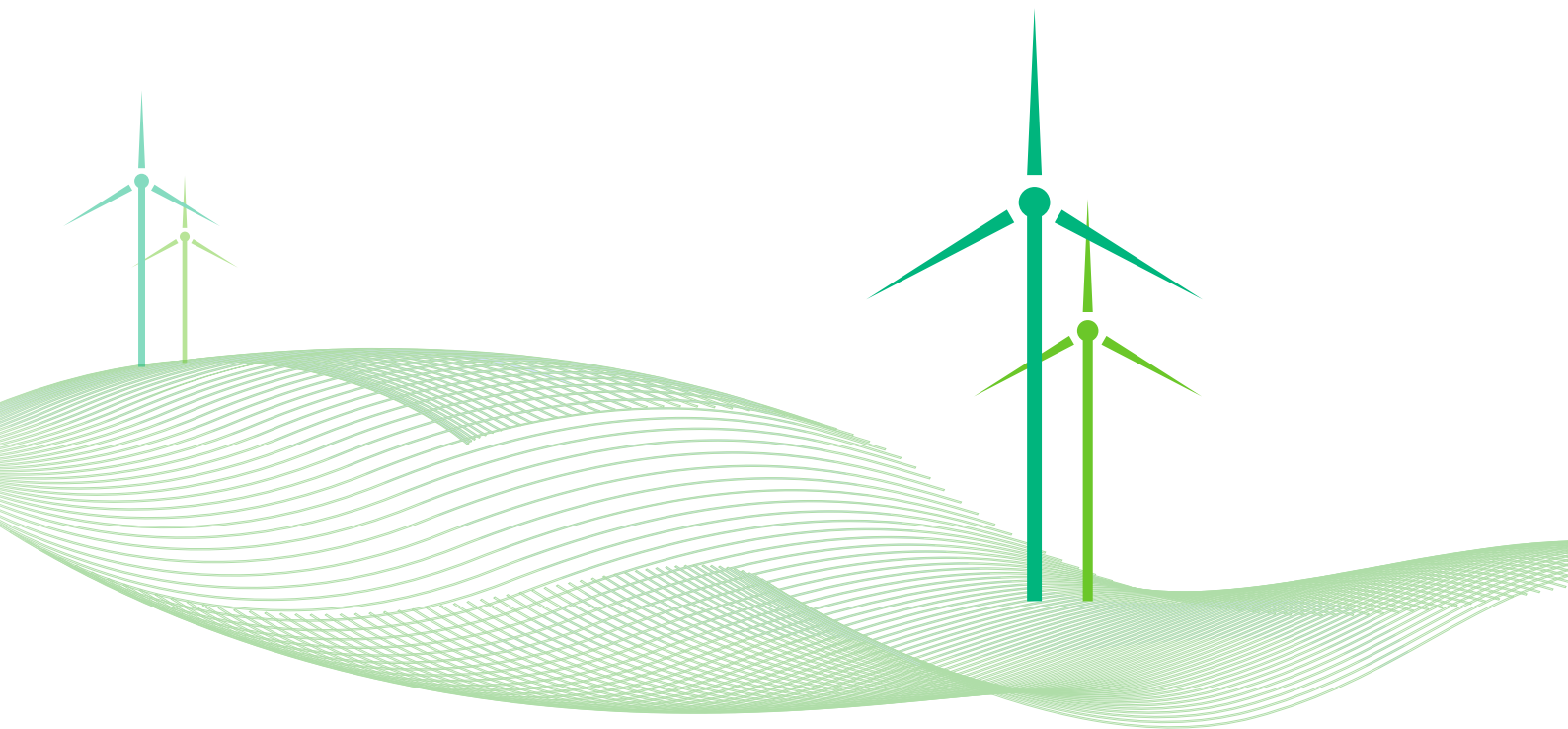
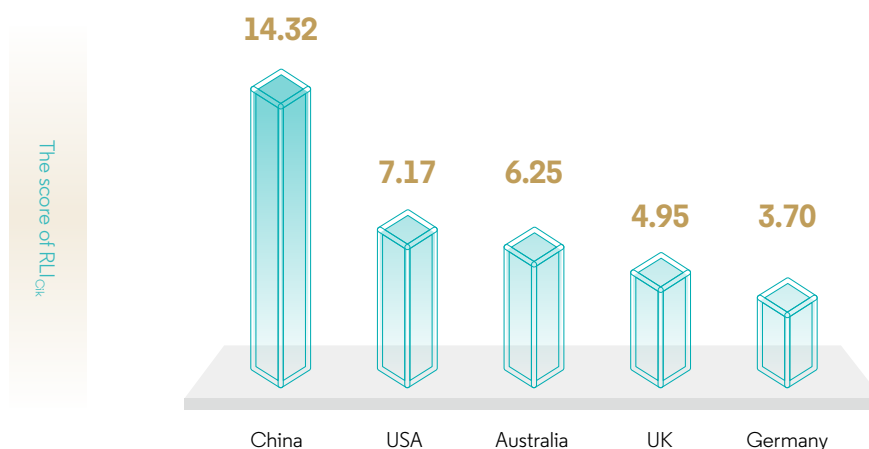


Table 7. The score and rank of the Top 5 countries based on RLI_{Cik} , $RFOI_{Cik}$ and $RFII_{Cik}$ in the area of “Ecology and environmental sciences”

Indicators	Score					Rank				
	China	USA	Australia	UK	Germany	China	USA	Australia	UK	Germany
RLI_{Cik}	14.32	7.17	6.25	4.95	3.70	1	2	3	4	5
$RFOI_{Cik}$	9.14	4.63	3.65	2.98	2.09	1	2	3	4	5
$RFII_{Cik}$	5.17	2.54	2.60	1.97	1.61	1	3	2	4	5



3.3 Geosciences: The USA ranks 1st; China and the UK are close; France and Germany are equally accomplished

In the area of “Geosciences”, the USA scores 16.02 in RLI_{Cik} , ranking 1st, far ahead of other countries. China and the UK score close at 10.28 and 9.17, ranking 2nd and 3rd, respectively. France and Germany register at 6.66 and 5.62, ranking 4th

and 5th, respectively. As can be seen in Table 8, the USA and France rank in the same order according to all three indicators. China, the UK, and Germany’s placements vary slightly according to the three indicators.

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

Indicators	Score					Rank				
	USA	China	UK	France	Germany	USA	China	UK	France	Germany
RLI_{Cik}	16.02	10.28	9.17	6.66	5.62	1	2	3	4	5
$RFOI_{Cik}$	9.36	6.95	5.32	3.49	3.15	1	2	3	4	6
$RFII_{Cik}$	6.66	3.32	3.85	3.17	2.48	1	3	2	4	5



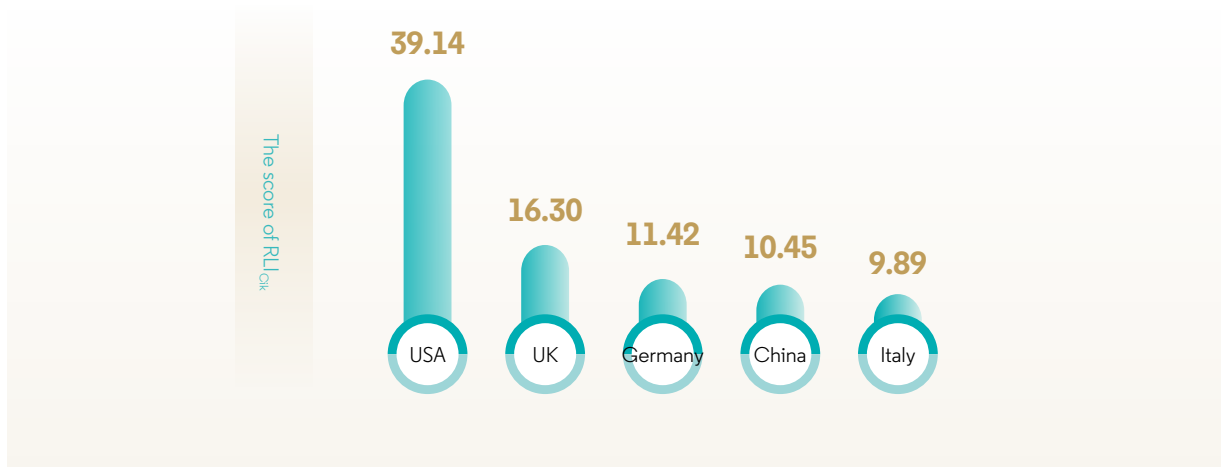
3.4 CLINICAL MEDICINE: The USA far exceeds other countries, the UK ranks 2nd; Germany, China, and Italy have close scores

In the area of “Clinical medicine”, the USA score 39.14 in RLI_{Cik} , respectively, ranking 1st, far ahead of other countries. The UK register at 16.30, less than half of America, ranking 2nd. Germany, China, and Italy score close to one another at 11.42, 10.45 and 9.89, ranking 3rd to 5th.

The respective rankings of the USA and the UK in RLI_{Cik} are identical to those in $RFOI_{Cik}$ and $RFII_{Cik}$. Germany, China, and Italy’s placements vary slightly according to the three indicators.

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

Indicators	Score					Rank				
	USA	UK	Germany	China	Italy	USA	UK	Germany	China	Italy
RLI_{Cik}	39.14	16.30	11.42	10.45	9.89	1	2	3	4	5
$RFOI_{Cik}$	23.52	9.24	6.83	5.63	6.39	1	2	3	5	4
$RFII_{Cik}$	15.62	7.07	4.59	4.82	3.50	1	2	4	3	5



3.5 BIOLOGICAL SCIENCES: The USA leads substantially, China is 2nd, with its RLI_{Cik} very close to the USA, while Germany, the UK and Australia rank 3rd to 5th

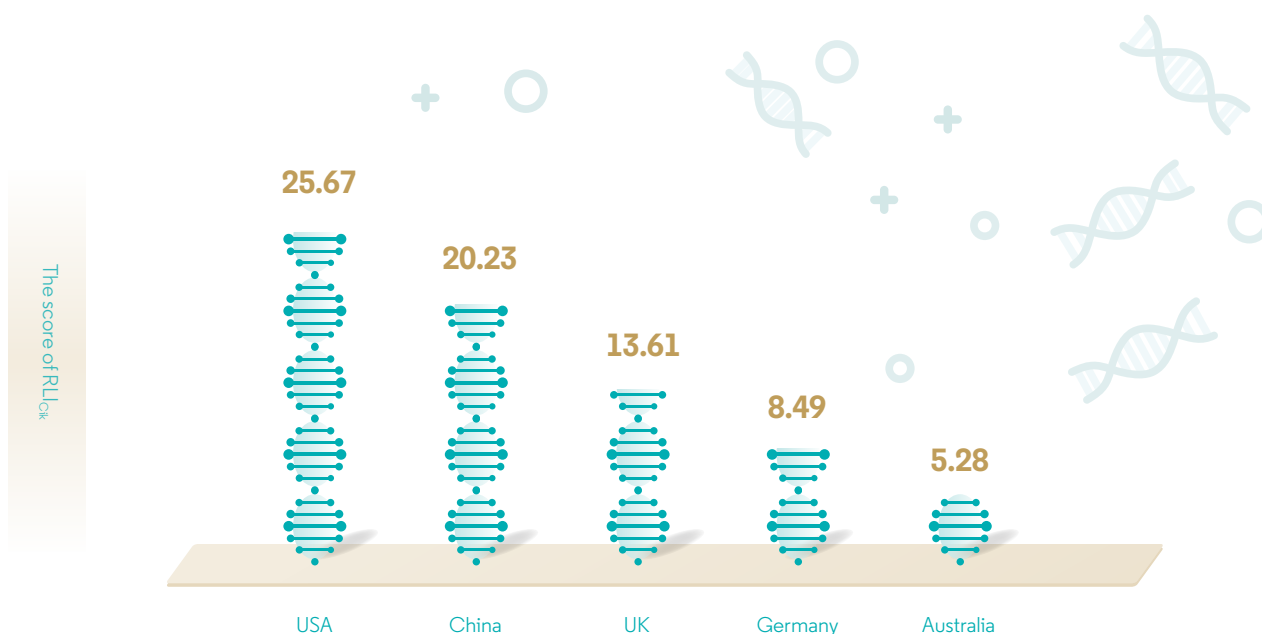
In the area of “Biological sciences”, the USA and China register at 25.67 and 20.23 in RLI_{Cik}, placing 1st and 2nd, with the scores far exceeding those of other countries. The UK scores 13.61, ranking 3rd. Germany and Australia score

8.49 and 5.28 respectively, ranking 4th, and 5th. The top four countries maintain the same rank order according to the three indicators.

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

Indicators	Score					Rank				
	USA	China	UK	Germany	Australia	USA	China	UK	Germany	Australia
RLI _{Cik}	25.67	20.23	13.61	8.49	5.28	1	2	3	4	5
RFOI _{Cik}	15.45	12.19	7.30	4.52	2.61	1	2	3	4	6
RFII _{Cik}	10.22	8.05	6.32	3.97	2.66	1	2	3	4	5





3.6 CHEMISTRY AND MATERIALS SCIENCE: China's RLI_{Cik} is 2.5 times that of the USA; China demonstrates outstanding advantages; Germany, South Korea, and Japan rank 3rd to 5th

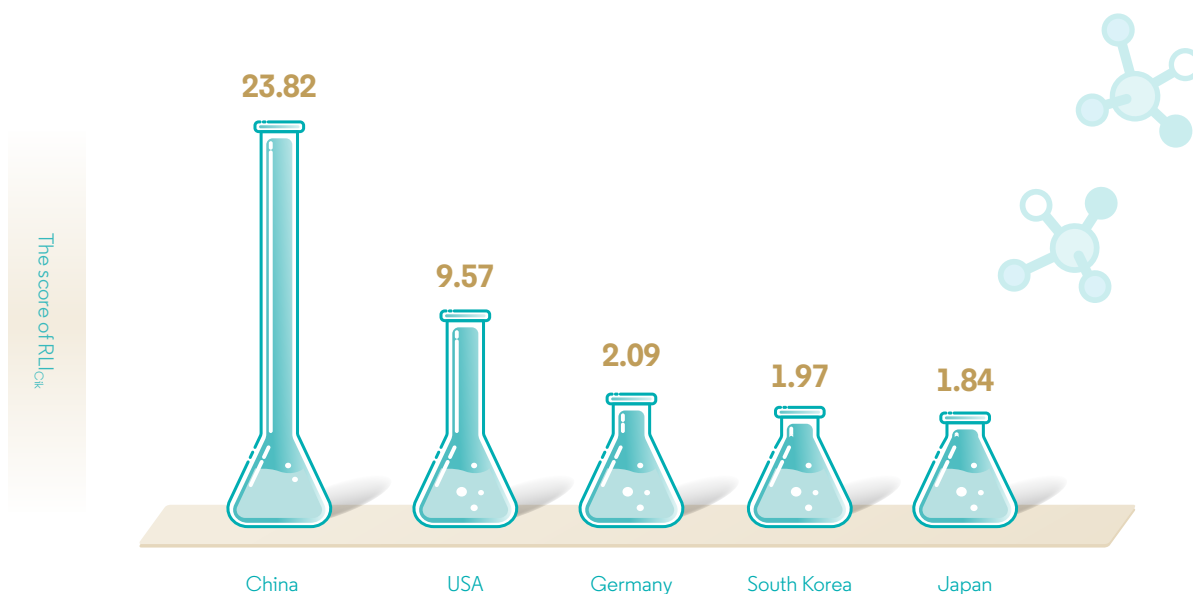
In the area of "Chemistry and materials science", China's RLI_{Cik} score is 23.82, which is 2.5 times that of the USA, earning China 1st place (Table 11). The USA scores 9.57, ranking 2nd. These scores indicate a significant activity gap between the USA and China in this area. Although the USA lags China by a large margin, it still far exceeds other countries. Germany,

South Korea, and Japan post marks of 2.09, 1.97, and 1.84 respectively, ranking 3rd to 5th. The rankings based on the indicators RLI_{Cik} , $RFOI_{Cik}$, and $RFII_{Cik}$ for China and the USA are the same, while the rankings of Germany, South Korea, and Japan vary slightly among the three indicators.



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	South Korea	Japan	China	USA	Germany	South Korea	Japan
RLI_{Cik}	23.82	9.57	2.09	1.97	1.84	1	2	3	4	5
$RFOI_{Cik}$	15.52	5.52	1.37	1.08	1.25	1	2	3	6	4
$RFII_{Cik}$	8.30	4.05	0.72	0.89	0.59	1	2	4	3	9



3.7 PHYSICS: China ranks 1st; the USA is 2nd, the RLI_{Cik} score of the USA is very close to China; Japan, Germany, and the UK are 3rd, 4th, and 5th

In the area of “Physics”, China posts the highest degree of activity with an RLI_{Cik} of 14.80, and the USA scores 12.74, ranking 2nd. China and the USA showing an overall leading trend, while Germany and Japan score close at 6.67 and 6.25,

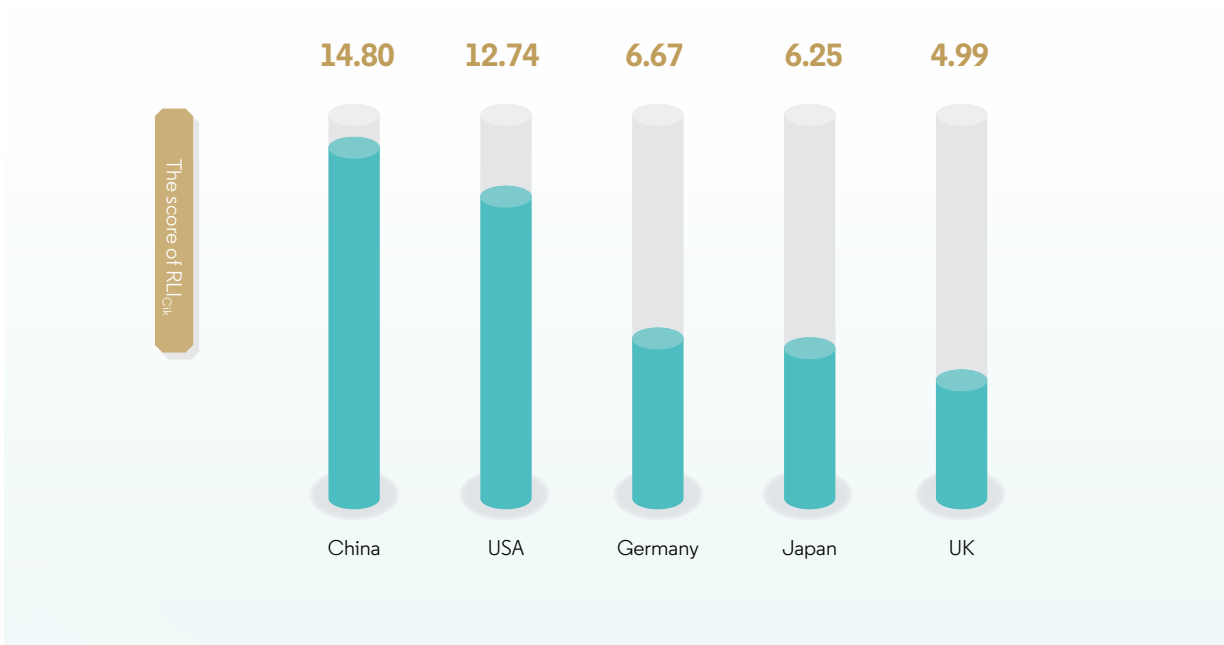
respectively. The UK scores 4.99, ranking in 5th place.

Germany, Japan, and the UK rank the same across all three indicators, while for China and the USA, the rankings based on the $RFII_{Cik}$ indicator display some variance.



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

Indicators	Score					Rank				
	China	USA	Germany	Japan	UK	China	USA	Germany	Japan	UK
RLI_{Cik}	14.80	12.74	6.67	6.25	4.99	1	2	3	4	5
$RFOI_{Cik}$	9.61	7.47	3.82	3.51	2.79	1	2	3	4	5
$RFII_{Cik}$	5.19	5.27	2.85	2.74	2.20	2	1	3	4	5



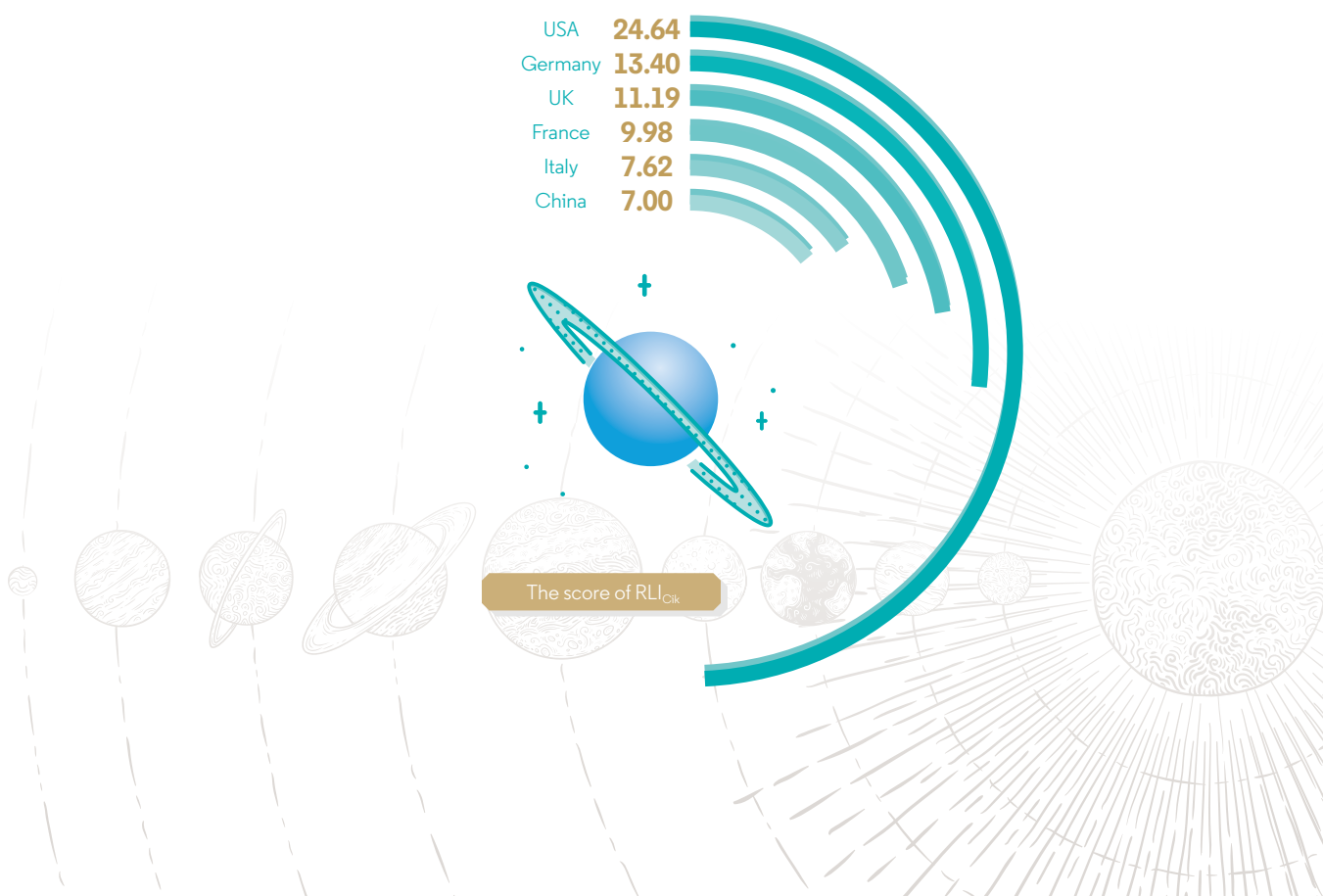
3.8 ASTRONOMY AND ASTROPHYSICS: The USA has a dominant position; Germany, the UK, France, and Italy rank 2nd to 5th; China is 7th

In the area of “Astronomy and astrophysics” (Table 13), the USA ranks 1st, with an RLI_{Cik} score of 24.64. Germany ranks 2nd with a mark of 13.40, with the UK 3rd at 11.19, followed by France (9.98) and Italy (7.62). China places 7th with a score

of 7.00, one place ahead of its showing in 2021. The top four countries rank in the same order on the three indicators, while Italy and China’s placements vary according to the different measures.

Table 13. The score and rank of the 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}	24.64	13.40	11.19	9.98	7.62	7.00	1	2	3	4	5	7
RFOI _{Cik}	14.85	7.71	6.68	5.60	4.48	4.30	1	2	3	4	5	6
RFII _{Cik}	9.79	5.69	4.51	4.38	3.14	2.70	1	2	3	4	6	8





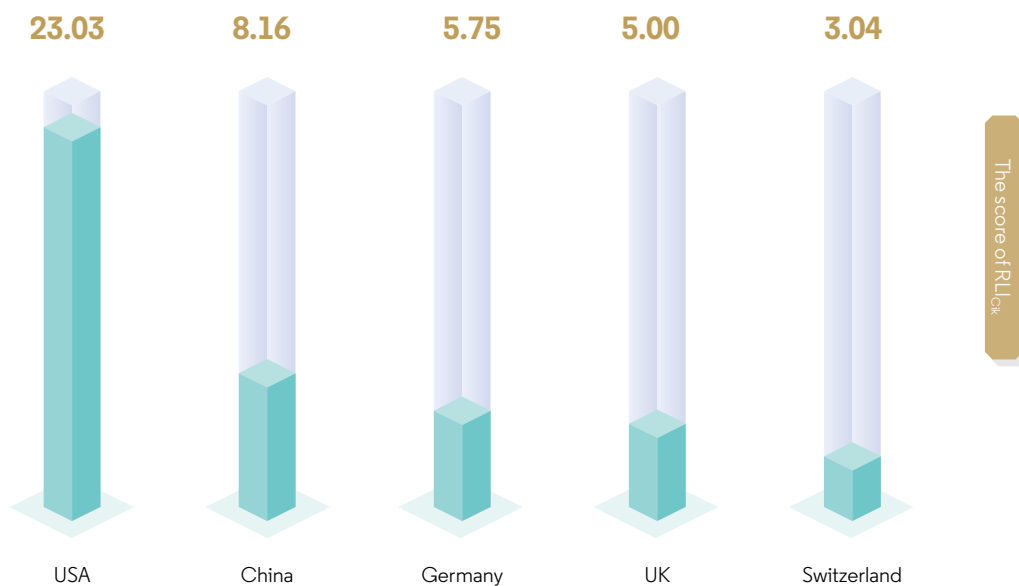
3.9 MATHEMATICS: The USA is the most active; China is 2nd; Germany, the UK, and Switzerland are 3rd to 5th

In the area of “Mathematics”, the USA achieves the most active performance and ranks 1st, with a score of 23.03. Meanwhile, China posts a score of 8.16, ranking 2nd. China and the USA are ahead of other countries, but there is still a large gap between

China and the USA. Germany and the UK score 5.75 and 5.00, respectively, ranking 3rd and 4th. Switzerland scores 3.04, ranking 5th. The rankings of the top five countries according to the three indicators are completely consistent.

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

Indicators	Score					Rank				
	USA	China	Germany	UK	Switzerland	USA	China	Germany	UK	Switzerland
RLI_{Cik}	23.03	8.16	5.75	5.00	3.04	1	2	3	4	5
$RFOI_{Cik}$	12.92	5.58	3.35	2.89	1.76	1	2	3	4	5
$RFII_{Cik}$	10.11	2.59	2.39	2.11	1.27	1	2	3	4	5



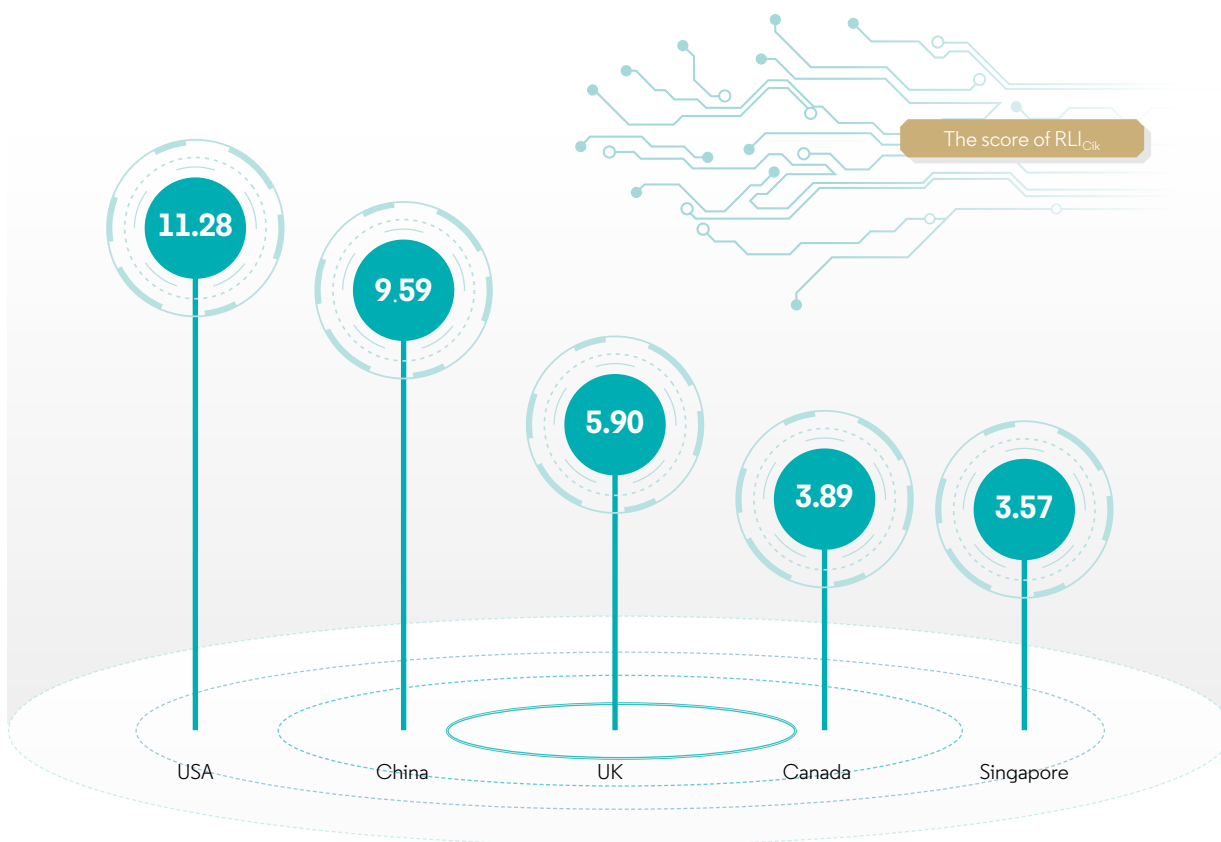
3.10 INFORMATION SCIENCE: China and the USA are the most active; the UK, Canada, and Singapore rank 3rd to 5th

In this area of “Information science”, the USA and China are the most active, with respective RLI_{Cik} scores of 11.28 and 9.59. The UK scores 5.90, ranking 3rd. Canada, and

Singapore score 3.89 and 3.57, ranking 4th to 5th, respectively. The rankings based on the three indicators for the top five countries tend to vary.

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

Indicators	Score					Rank				
	USA	China	UK	Canada	Singapore	USA	China	UK	Canada	Singapore
RLI_{Cik}	11.28	9.59	5.90	3.89	3.57	1	2	3	4	5
$RFOI_{Cik}$	6.53	7.18	3.33	2.34	1.83	2	1	3	4	5
$RFII_{Cik}$	4.75	2.42	2.57	1.55	1.75	1	3	2	5	4



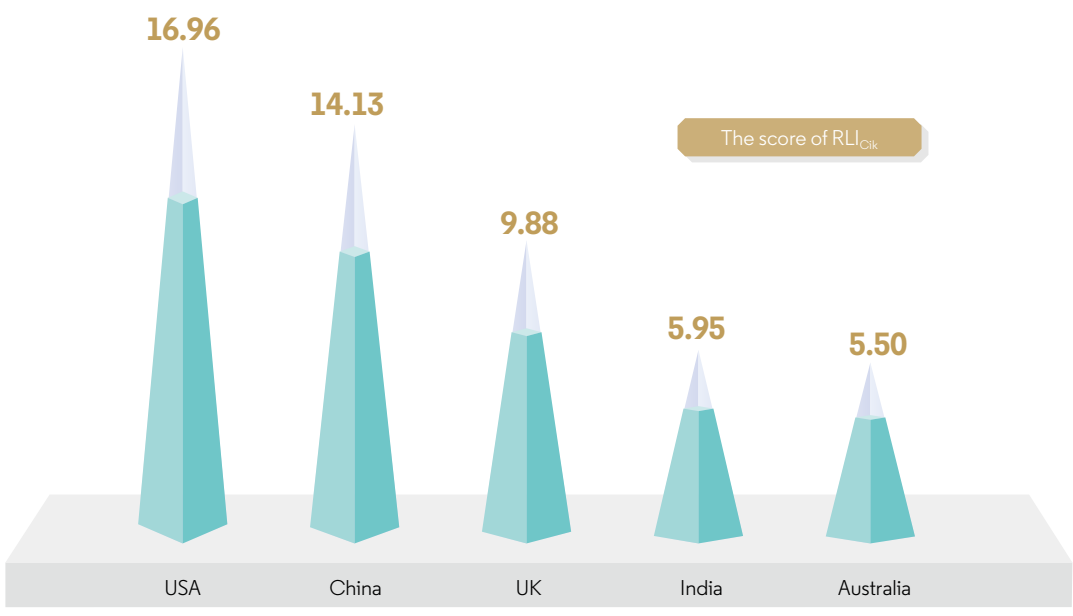
3.11 ECONOMICS, PSYCHOLOGY AND OTHER SOCIAL SCIENCES: The scores of the USA and China are close; the UK, India, and Australia rank 3rd to 5th

In this area of “Economics, psychology and other social sciences”, the RLI_{Cik} scores of the USA and China are very close, at 16.96 and 14.13, respectively. The UK scores 9.88, ranking 3rd. India and Australia rank 4th and 5th with 5.95 and

5.50, respectively. For the USA, China, the UK, and India, the rankings based on the indicators RLI_{Cik} , $RFOI_{Cik}$ and $RFII_{Cik}$ are the same across the board, contrasting with the varying placements by Australia according to the three measures.

Table 16. The score and rank of the 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	India	Australia	USA	China	UK	India	Australia
RLI_{Cik}	16.96	14.13	9.88	5.95	5.50	1	2	3	4	5
$RFOI_{Cik}$	10.76	9.16	5.66	3.73	3.58	1	2	3	4	5
$RFII_{Cik}$	6.19	4.97	4.22	2.22	1.92	1	2	3	4	6



2022 Research Fronts: Active Fields, Leading Countries



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