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

Clarivate™

2024

Research Fronts: Active Fields, Leading Countries/Regions

Institutes of Science and Development,
Chinese Academy of Sciences

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2024 Research Fronts: Active Fields, Leading Countries/Regions

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 2024” report is a prequel to another survey, “Research Fronts 2024: Active Fields, Leading Countries/Regions”, which selects and discusses 110 hot fronts and 15 emerging fronts in 11 broad research areas. Based on the findings of “Research Fronts 2024”, this second report uses the Research Leadership Index to assess the research activity of the world’s major countries/regions and to observe how that activity, in the face of global competition in innovation and technological advancement, is demonstrated in these Research Fronts.

110个

Hot Research Fronts

15个

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 considers 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.

The entities measured by the Research Leadership Index can be countries/regions, 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.

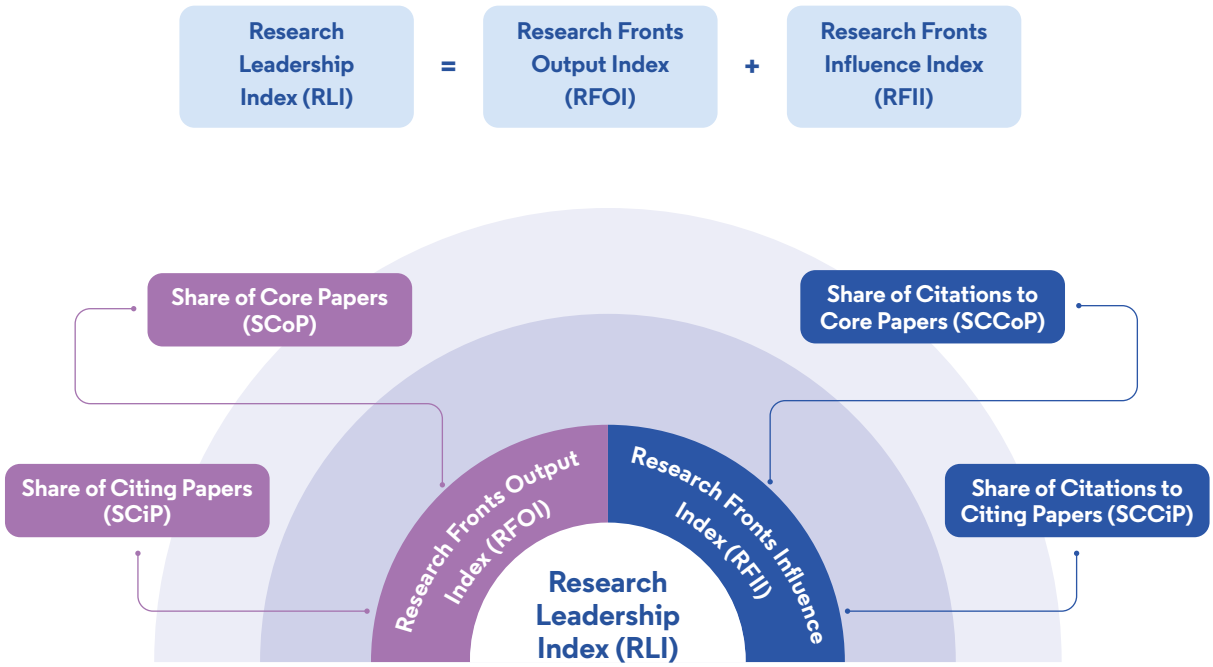


Figure 1. The logic model of Research Leadership Index (RLI)

1.2 Research Leadership Index of Country/region (RLIC)

This report calculates the Research Leadership Index of main countries/regions at the Research Front level, area level, and the level of all 11 broad research areas. Based on that, the report determines the degree of activity in innovation and its pattern within the main countries/regions as reflected in Research Fronts, and reveals the sources of research vitality in various countries/regions. The methods for calculation and analysis are as follows:

1.2.1 Research Leadership Index of a country/region in a Research Front (RLI_{Cij})

The Research Leadership Index measures a country/region'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/region 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/region, $RFII_{Cij}$ is the Research Fronts Influence Index of a country/region, j represents the Research Front, and i represents each country/region.

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

The Research Fronts Output Index of a country/region ($RFOI_{Cij}$) is the relative share of the number of papers (core papers and citing papers) contributed by a country/region to the literature that constitutes a Research Front. $RFOI_{Cij}$ equals 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/region'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/region i in Research Front j; CoP_j represents the number of core papers in Research Front j.

A country/region'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/region 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/region ($RFII_{Cij}$)

The Research Fronts Influence Index of a country/region ($RFII_{Cij}$) is the relative share of the citation of papers (core and citing) that a country/region contributed in a Research Front. $RFII_{Cij}$ equals the sum of the two indicators $SCCoP_{Cij}$ and $SCCiP_{Cij}$.

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

A country/region'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/region i in Research Front j; CoC_j represents the citation of core papers in Research Front j.

The measure known as Country/region'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/region 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/region in an area (RLI_{Cik})

The Research Leadership Index of country/region i in area k (RLI_{Cik}) is the summation of the Research Leadership Index of country/region 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} is equal to the sum of the two indicators $RFOI_{Cik}$ and $RFII_{Cik}$.

(1)Research Fronts Output Index of a country/region in an area ($RFOI_{Cik}$)

The Research Fronts Output Index of a country/region in an area ($RFOI_{Cik}$) is the relative share of the number of papers (core and citing) contributed by a country/region to an area comprising 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/region's Share of Core Papers in an area ($SCoP_{Cik}$) is below:

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

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

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

(2)Research Fronts Influence Index of a country/region in an area ($RFII_{Cik}$)

The Research Fronts Influence Index of a country/region in an area ($RFII_{Cik}$) is the relative share of the citation of papers (core and citing) contributed by a country/region to an area comprising n Research Fronts. $RFII_{Cik}$ equals 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/region's Share of Citations to Core Papers in an area ($SCCoP_{Cik}$) is:

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

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

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

1.1.3Research Leadership Index of a country/region in 11 broad research areas (RLI_{Ci})

The Research Leadership Index of a country/region 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/region based on its contribution to 11 broad research areas comprising 125 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/region in 11 broad research areas ($RFOI_{Ci}$)

The Research Fronts Output Index of a country/region 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/region to 11 broad research areas comprising 125 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/region'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/region's Share of Citing Papers in 11 broad research areas ($SCiP_{Ci}$) is:

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

(2)Research Fronts Influence Index of a country/region in 11 broad research areas ($RFII_{Ci}$)

The Research Fronts Influence Index of a country/region 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/region to 11 broad research areas comprising 125 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/region'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/region'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/Regions

We measured the RLI_{ci} of main countries/regions for overall performance in 11 broad research areas comprising 125 Research Fronts and ranked the top countries/regions. The following highlights are noted.

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

Based on 11 broad research areas and each country/region's respective performance in the 125 constituent Research Fronts, the USA is the most active, with an RLI_{Ci} score of 193.69, ranking 1st (Figure 2). China ranks 2nd with a score of 152.19, approximately 78.6% of the USA. Both the USA and China have a solid position, unmatched by any other countries/regions. The UK and Germany score 76.80 and 64.26, respectively, ranking 3rd and 4th, in the second tier, holding a significant advantage compared to France, ranked 5th, with a score of 46.73 (Figure 2).

Italy, Australia, Canada, Spain, and Switzerland rank 6th to 10th in terms of RLI_{Ci} score. The Netherlands and Japan rank 11th and 12th. South Korea ranks 13th, followed by Belgium and India.

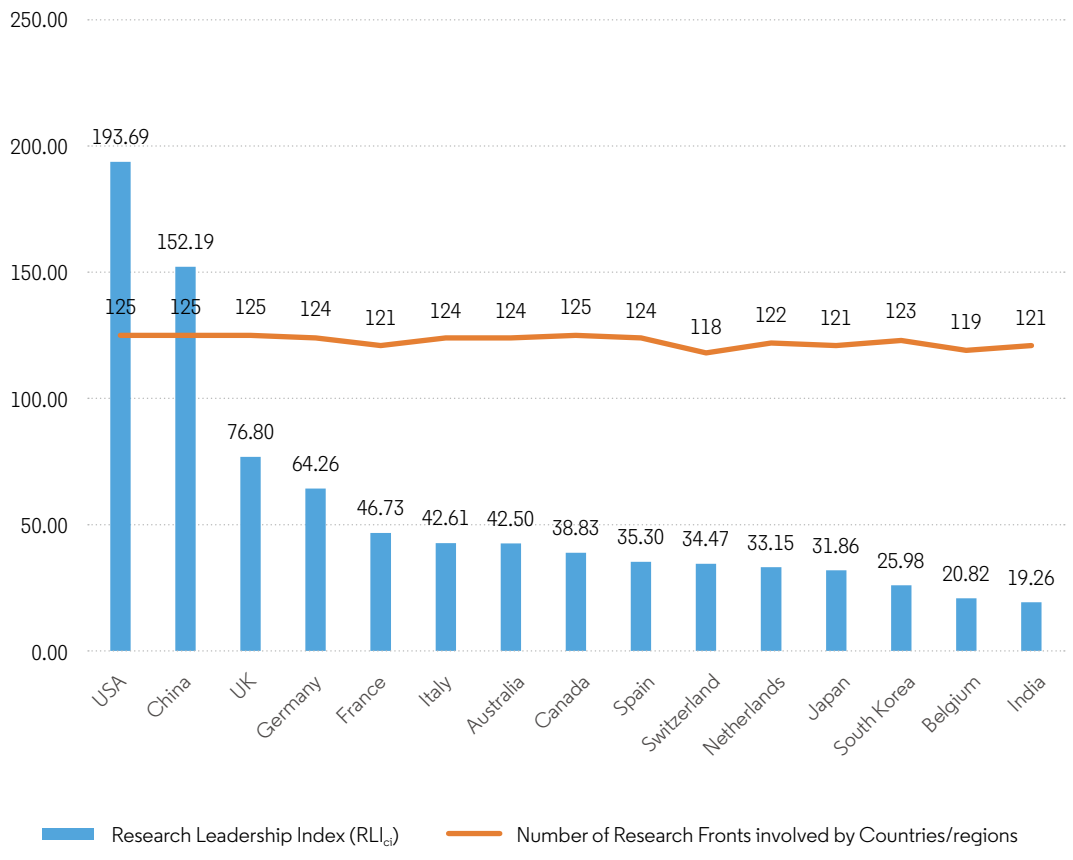


Figure 2. Research Leadership Index (RLI_{Ci}) of Top 15 Countries/Regions in 11 broad research areas with 125 Research Fronts

Table 1 shows that the rank order for the three indicators RLI_{Ci}, RFOICi, and $RFII_{Ci}$ for the top five countries/regions is the same. For the remaining countries/regions, scores on the three indicators do not differ widely, although precise calculation ranks the countries/regions from 6th to 15th.

Table 1. The Research Leadership Index (RLI_{Ci}) of Top 15 Countries/regions in 11 broad research areas with 125 Research Fronts

	RLI_{Ci}		$RFOI_{Ci}$		$RFII_{Ci}$	
Countries/regions	**Score**	**Rank**	**Score**	**Rank**	**Score**	**Rank**
USA	193.69	1	98.53	1	95.16	1
China	152.19	2	88.24	2	63.95	2
UK	76.80	3	37.91	3	38.89	3
Germany	64.26	4	31.28	4	32.98	4
France	46.73	5	22.18	5	24.55	5
Italy	42.61	6	21.54	6	21.07	7
Australia	42.50	7	20.68	7	21.82	6
Canada	38.83	8	18.64	8	20.18	8
Spain	35.30	9	17.39	9	17.90	10
Switzerland	34.47	10	16.44	10	18.03	9
Netherlands	33.15	11	15.43	12	17.72	11
Japan	31.86	12	16.02	11	15.84	12
South Korea	25.98	13	13.21	13	12.77	13
Belgium	20.82	14	9.16	15	11.66	14
India	19.26	15	10.51	14	8.76	17

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

For the 11 broad research areas, the USA's RLI_{Ci} scores are 1st in seven of the main areas: "Ecology and environmental science", "Geosciences", "Clinical medicine", "Biological sciences", "Astronomy and astrophysics", "Mathematics", 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 rank 1st in four areas: "Agricultural, plant and animal sciences", "Chemistry and materials science", "Physics", and "Information science". China ranks 2nd in three areas: "Ecology and environmental science", "Biological sciences", and "Mathematics", while ranking, respectively, 3rd and 4th in "Economics, psychology and other social sciences" and "Geosciences", and 6th in both "Clinical medicine", and "Astronomy and astrophysics" (Table 2).

"Clinical medicine" and "Astronomy and astrophysics" have consistently been areas in which China's RLI_{Ci} scores are relatively low. We compared the changes of RLI_{Ci} in these two areas in the last eight years. From 2017 to 2024, China ranked 10th, 13th, 9th, 12th, 1st, 4th, 9th, and 6th in terms of RLI_{Ci} in "Clinical medicine", in which the research on COVID-19 in 2021 and 2022 accounted for a large proportion, directly elevating China's ranking in "Clinical medicine". In 2023, China returned to the level of 2019. As of 2024, the nation has improved by three places compared to 2023. Meanwhile, China ranked 11th, 19th, 11th, 8th, 8th, 7th, 8th, and 6th respectively in "Astronomy and astrophysics" for the last eight years, showing a stable and upward trend.

Table 2. The score and rank of RLI_{Ci} and RLI_{Cik} of Top15 Countries/Regions

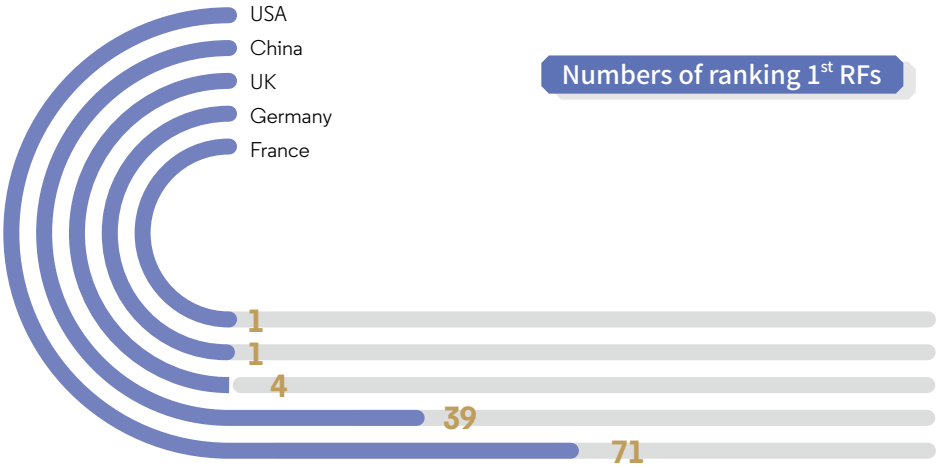
Countries/ regions			Agricultural, plant and animal sciences		Ecology and environmental science		Geosciences		Clinical medicine		Biological science		Chemistry and materials science		Physics		Astronomy and astrophysics.		Mathematics		Information science		Economics, psychology and other social sciences	
	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	193.69	1	8.44	2	12.10	1	21.97	1	28.45	1	23.35	1	9.72	2	12.81	2	23.45	1	20.46	1	12.17	2	20.77	1
China	152.19	2	22.21	1	10.57	2	8.76	4	8.40	6	14.99	2	29.48	1	12.90	1	13.50	6	7.00	2	17.45	1	6.94	3
UK	76.80	3	1.80	10	5.49	3	10.60	2	11.25	2	9.04	3	2.44	5	2.83	5	17.53	2	2.26	6	4.99	3	8.58	2
Germany	64.26	4	2.81	7	4.50	4	8.27	5	8.94	5	6.13	4	2.53	4	3.86	3	16.01	3	5.81	3	1.57	8	3.82	5
France	46.73	5	1.35	14	1.61	11	9.25	3	7.32	8	2.69	8	1.32	10	1.20	16	13.54	5	3.51	5	1.77	7	3.18	6
Italy	42.61	6	0.92	20	2.58	7	4.10	11	9.48	4	2.76	7	0.78	14	1.99	9	14.68	4	1.94	7	1.33	9	2.06	11
Australia	42.50	7	1.61	11	4.45	5	7.99	6	5.44	10	2.97	6	1.60	9	1.34	13	9.67	11	0.41	14	2.88	5	4.15	4
Canada	38.83	8	0.84	22	3.77	6	5.09	8	9.70	3	1.33	15	1.00	11	1.81	12	10.12	9	1.18	8	1.04	10	2.96	7
Spain	35.30	9	1.08	18	1.44	13	4.48	10	7.34	7	1.75	13	0.89	13	2.03	7	13.03	7	0.84	11	0.84	13	1.58	14
Switzerland	34.47	10	0.32	34	2.39	8	6.35	7	3.93	14	2.44	9	0.34	23	2.01	8	8.88	12	3.96	4	1.03	11	2.81	8
Netherlands	33.15	11	0.83	23	2.39	9	3.44	12	4.31	12	3.84	5	0.45	18	1.90	11	12.68	8	0.86	10	0.24	26	2.21	9
Japan	31.86	12	1.09	17	1.17	16	4.83	9	6.65	9	1.63	14	1.84	7	3.44	4	10.04	10	0.37	16	0.48	16	0.33	35
South Korea	25.98	13	2.40	9	1.23	15	1.28	21	3.56	15	2.09	12	3.10	3	2.25	6	7.15	15	0.35	17	1.88	6	0.70	21
Belgium	20.82	14	1.46	12	0.71	23	2.40	13	5.04	11	2.27	10	0.42	21	0.24	32	6.51	18	0.24	22	0.40	22	1.14	16
India	19.26	15	4.24	4	1.44	12	0.52	27	0.70	30	0.47	23	0.73	16	1.95	10	7.60	13	0.25	21	0.44	19	0.91	18

Among the 110 hot Research Fronts and 15 emerging Research Fronts in 11 broad research areas, the USA ranks 1st in 71, accounting for 56.80% of the 125 Research Fronts. China earns the top spot in 39 fronts, or 31.20%. The UK is tops in four Research Fronts, while Germany and France each rank 1st in one (Table 3). The first-ranked Research Fronts held by the USA and China account for about 88% of the 125 specialty areas. The UK and Germany together make up about 4%, while the remaining top-ranked fronts are shared by 10 countries/regions.

Of the 11 broad research areas, there are eleven fronts within "Chemistry and materials science" in which China ranks 1st, compared to only two for the USA. In the areas of "Agricultural, plant and animal sciences", the number of fronts in which China ranks 1st also exceeds that of the USA. In the area of "Ecology and environmental sciences", "Physics", and "Information science", the number of fronts in which China ranks 1st is almost equal to that of the USA. In the five areas of "Geosciences", "Biological sciences", "Astronomy and astrophysics", "Mathematics", and "Economics, psychology and other social sciences", the numbers of fronts in which China ranks 1st are all significantly fewer than those of the USA. In "Clinical medicine", China does not have any fronts ranked 1st, while the USA has at least 85% of the fronts ranking 1st, leaving a huge gap between China and the USA (Table 3).

Table 3. The numbers and ratios of the Research Fronts in which the respective Top 5 countries/regions rank first, out of 125 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	125	71	39	4	1	1	56.80%	31.20%	3.20%	0.80%	0.80%
Agricultural, plant and animal sciences	12	2	7	0	0	0	16.67%	58.33%	0.00%	0.00%	0.00%
Ecology and environmental sciences	10	5	4	0	0	0	50.00%	40.00%	0.00%	0.00%	0.00%
Geosciences	10	6	1	1	0	0	60.00%	10.00%	10.00%	0.00%	0.00%
Clinical medicine	14	12	0	1	0	0	85.71%	0.00%	7.14%	0.00%	0.00%
Biological sciences	14	10	3	1	0	0	71.43%	21.43%	7.14%	0.00%	0.00%
Chemistry and materials science	13	2	11	0	0	0	15.38%	84.62%	0.00%	0.00%	0.00%
Physics	10	5	5	0	0	0	50.00%	50.00%	0.00%	0.00%	0.00%
Astronomy and astrophysics	11	10	1	0	0	0	90.91%	9.09%	0.00%	0.00%	0.00%
Mathematics	10	7	1	0	1	1	70.00%	10.00%	0.00%	10.00%	10.00%
Information science	10	4	5	0	0	0	40.00%	50.00%	0.00%	0.00%	0.00%
Economics, psychology and other social sciences	11	8	1	1	0	0	72.73%	9.09%	9.09%	0.00%	0.00%

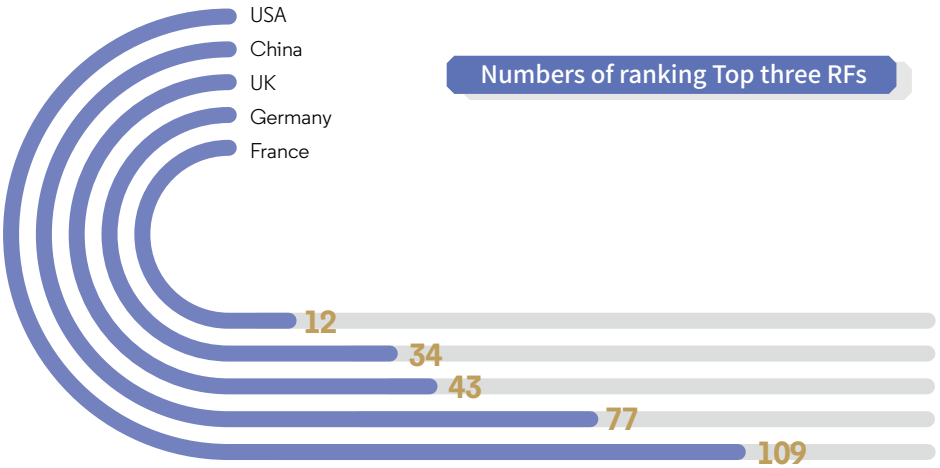


Among countries/regions ranking among the top three performers in the 125 Research Fronts (Table 4), the USA earns that distinction in 109 fronts, or 87.20%, China in 77 Research Fronts (61.60%), the UK in 43, Germany in 34, and France in 12, with the latter three countries/regions able to boast the achievement in 34.40%, 27.20% and 9.60% of the total number of Research Fronts, respectively (Table 4).

Table 4. The numbers and ratios of countries/regions ranking among the top three performers in Research Fronts, among the Top 5 countries/regions in 11 broad research areas with 125 Research Fronts (based on RLI_{Ci})

Areas	Numbers of RFs	Numbers of ranking Top three RFs					Ratios (%)				
		USA	China	UK	Ger-many	France	USA	China	UK	Germany	France
11 broad research areas total	125	109	77	43	34	12	87.20%	61.60%	34.40%	27.20%	9.60%
Agricultural, plant and animal sciences	12	8	10	1	3	0	66.67%	83.33%	8.33%	25.00%	0.00%
Ecology and environmental sciences	10	8	5	3	3	0	80.00%	50.00%	30.00%	30.00%	0.00%
Geosciences	10	9	4	3	1	4	90.00%	40.00%	30.00%	10.00%	40.00%
Clinical medicine	14	14	4	5	4	2	100.00%	28.57%	35.71%	28.57%	14.29%
Biological sciences	14	14	8	7	3	1	100.00%	57.14%	50.00%	21.43%	7.14%
Chemistry and materials science	13	10	13	3	4	1	76.92%	100.00%	23.08%	30.77%	7.69%

Areas	Numbers of RFs	Numbers of ranking Top three RFs					Ratios (%)				
		USA	China	UK	Ger-many	France	USA	China	UK	Germany	France
Physics	10	9	8	2	3	0	90.00%	80.00%	20.00%	30.00%	0.00%
Astronomy and astrophysics	11	11	3	7	7	1	100.00%	27.27%	63.64%	63.64%	9.09%
Mathematics	10	8	6	1	4	1	80.00%	60.00%	10.00%	40.00%	10.00%
Information science	10	8	10	3	1	1	80.00%	100.00%	30.00%	10.00%	10.00%
Economics, psychology and other social sciences	11	10	6	8	1	1	90.91%	54.55%	72.73%	9.09%	9.09%



The USA makes the top three in more than 66.67% of the respective Research Fronts associated with each of the 11 broad specialty areas. In the three areas of "Clinical medicine", "Biological Sciences", 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 "Geosciences", "Physics", and "Economics, psychology and other social sciences", in which the USA ranks among the top three in 90%. In the three areas of "Ecology and environmental sciences", "Mathematics", and "Information science", the USA ranks among the top three performers in 80% of the pertinent Research Fronts. In the two areas of "Agricultural, plant and animal sciences", "Chemistry and materials science", meanwhile, the USA's proportions of top three range from 66.67%-76.92%.

China's proportion of top-three placement ratios reaches 100% in "Chemistry and material science" and "Information science", while in "Agricultural, plant and animal sciences" and "Physics", this score equals or exceeds 80%. China registers among the top three reaching or exceeding 50% in "Ecology and environmental sciences", "Biological Sciences", "Mathematics", and "Economics, psychology and other social sciences". The nation's ratio of top three fronts in the four areas of, "Geosciences", "Clinical medicine", and "Astronomy and astrophysics" is 40%, 28.57%, and 27.27%, respectively (Figure 3).

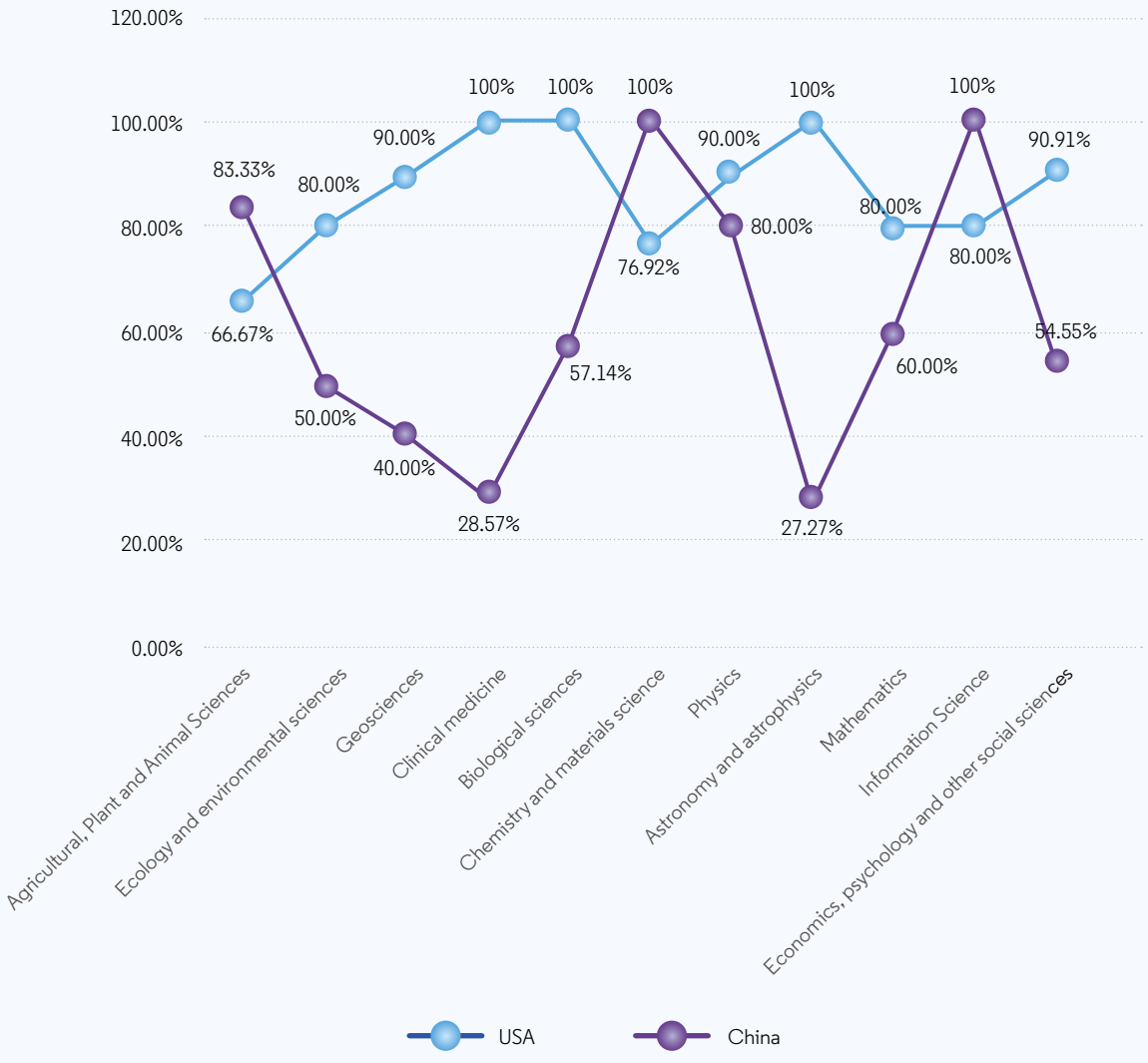


Figure 3. The ratios of the ranking top three Research Fronts for China and the USA in 11 broad research areas with 125 Research Fronts (based on RLI_{Ci})

The UK has the highest proportion of top three Research Fronts in "Economics, psychology and other social sciences" and "Astronomy and astrophysics", ranging from 72.73% to 63.64%, respectively, compared to other fields. The UK's ratio of top three fronts in "Biological Sciences" is 50%. In "Clinical medicine", the UK ranks among the top three performers in 35.71% of the pertinent Research Fronts.

In "Ecology and environmental sciences", "Geosciences", and "Information science", the UK's presence in the top three ranges is 30% of Research Fronts. In "Agricultural, Plant and Animal Sciences", "Chemistry and materials science", and "Physics", the proportion of top-three placement ratios come in at 8.33%, 23.08%, and 20%.

Germany has its highest proportion of top three Research Fonts in "Astronomy and astrophysics", accounting for 63.64%, representing the nation's dominant performance. In "Mathematics", the proportion of top-three placement ratios register at 40%. The proportion in both "Geosciences" and "Information sciences" is 10%, while the proportion in "Economics, psychology, and other social sciences" is the lowest, at 9.09%.

France has the highest percentage of the top three Research Fronts in "Geosciences", at 40%. In the other seven fields, the proportion ranges from 7.14% to 14.29%. In "Agricultural, plant and animal sciences", "Ecology and environmental sciences", and "Physics", France has no fronts ranked in the top three (Figure 4).

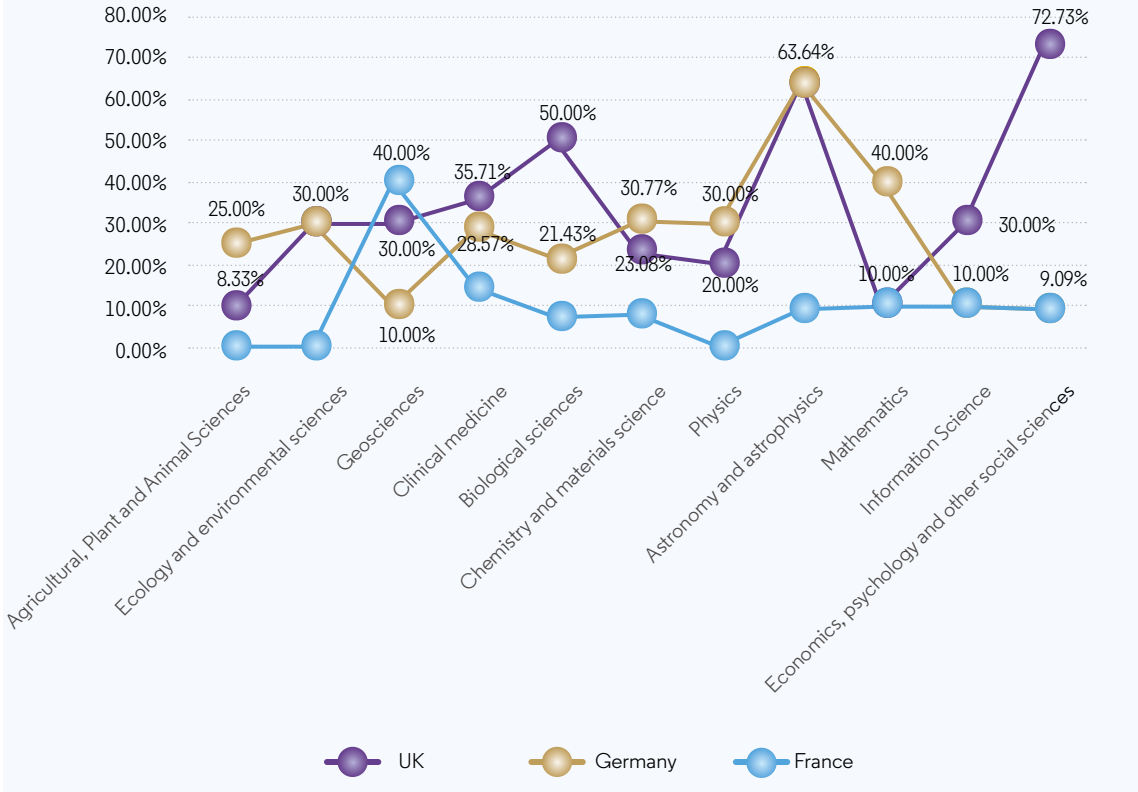


Figure 4. The ratios of Research Fronts in which the UK, Germany, and France rank among the top three performers, in 11 broad research areas comprising 125 Research Fronts (based on RLI_{Ci})

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

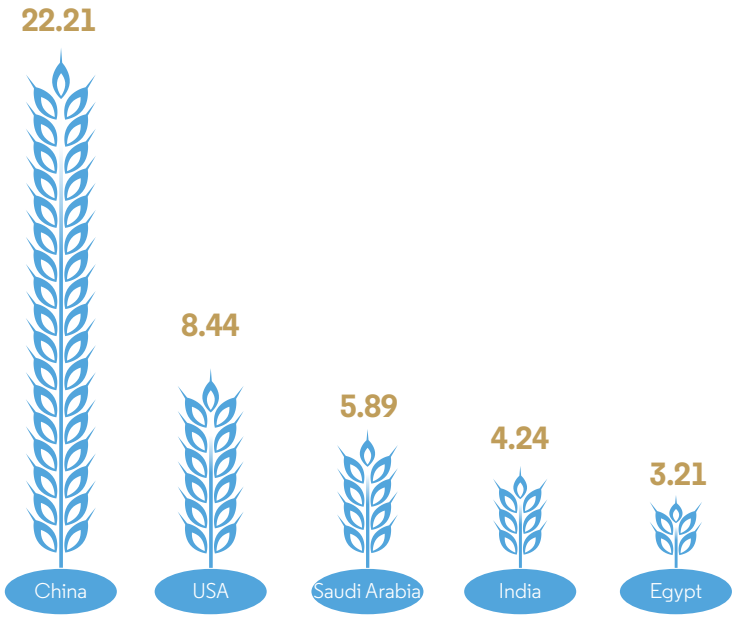
This section highlights the scores and rankings obtained via the RLI_{Cik} measurement, exploring the Research Front activity and influence of various countries/regions in specific areas, and analyzing the respective sources of national vitality in scientific and technical innovation.

3.1 AGRICULTURAL, PLANT AND ANIMAL SCIENCES: China has an obvious advantage; the USA is 2nd; Saudi Arabia, India, and Egypt are the 3rd to 5th

In "Agricultural, plant and animal sciences", China's performance is the most eye-catching according to its RLI_{Cik} score of 22.21, ranking 1st (Table 5). The USA scores 8.44, ranking 2nd. Saudi Arabia scores 5.89, ranking 3rd. India and Egypt post scores close to each other, ranking 4th, and 5th, respectively. As can be seen from Table 5, the ranking according to $RFII_{Cik}$ and $RFOI_{Cik}$ is the same as RLI_{Cik} for the Top 5 countries.

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

	Score					Rank				
Indicators	China	USA	Saudi Arabia	India	Egypt	China	USA	Saudi Arabia	India	Egypt
RLI_{Cik}	22.21	8.44	5.89	4.24	3.21	1	2	3	4	5
$RFOI_{Cik}$	12.91	4.51	2.94	2.47	1.69	1	2	3	4	5
$RFII_{Cik}$	9.30	3.94	2.95	1.77	1.52	1	2	3	4	5



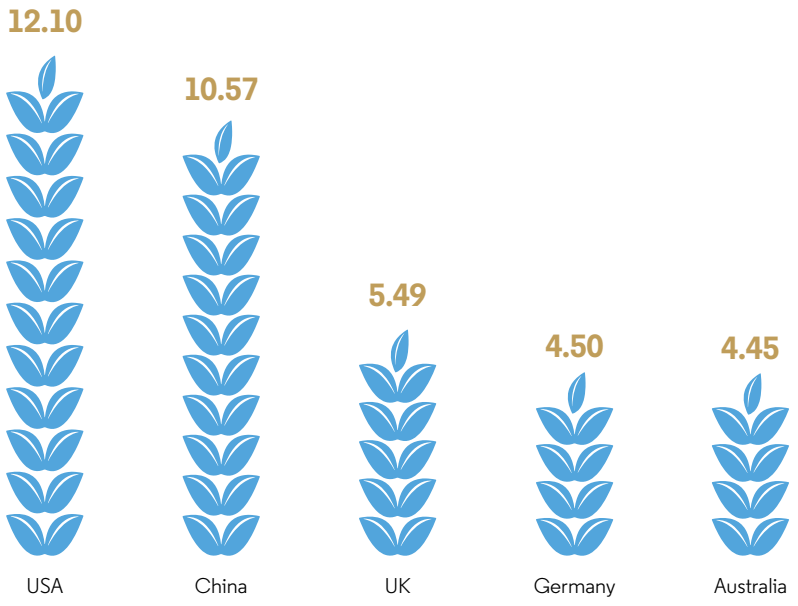
The score of RLI_{Cik}

3.2 ECOLOGY AND ENVIRONMENTAL SCIENCES: the USA leads; China follows closely; the UK, Germany, and Australia rank 3rd to 5th

In "Ecology and environmental sciences" (Table 6), the USA scores 12.10 in RLI_{Cik}, ranking 1st, demonstrating the most activity. China scores 10.57, ranking 2nd. The UK scores 5.49, ranking 3rd. Germany and Australia are in 4th and 5th place, with respective scores of 4.50 and 4.45. The rank order of the Top 3 countries/regions remains the same for all three indicators: RLI_{Cik}, $RFOI_{Cik}$, and $RFII_{Cik}$.

Table 6. The score and rank of the Top 5 countries/regions based on RLI_{Cik}, $RFOI_{Cik}$ and $RFII_{Cik}$ in "Ecology and environmental sciences"

	Score					Rank				
Indicators	USA	China	UK	Germany	Australia	USA	China	UK	Germany	Australia
RLI_{Cik}	12.10	10.57	5.49	4.50	4.45	1	2	3	4	5
$RFOI_{Cik}$	6.21	6.08	2.81	2.12	2.15	1	2	3	5	4
$RFII_{Cik}$	5.89	4.48	2.68	2.38	2.29	1	2	3	4	5



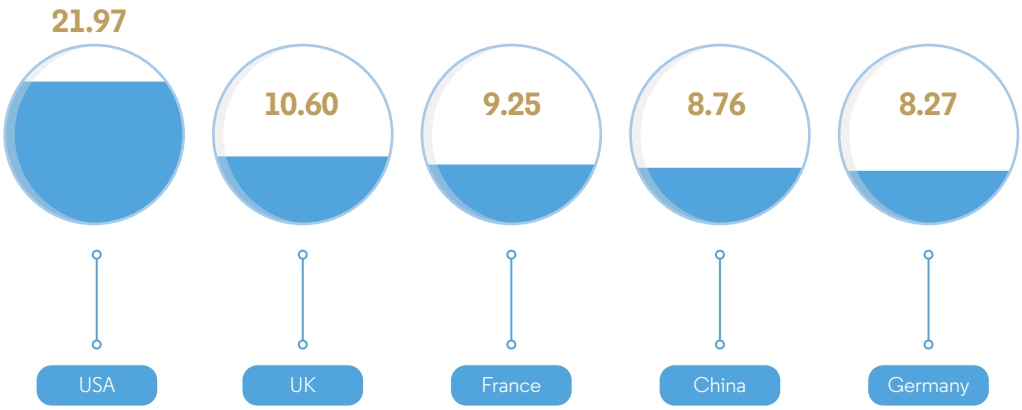
The score of RLI_{Cik}

3.3 Geosciences: The USA ranks 1st; the UK is 2nd; France, China, and Germany are equally accomplished

In "Geosciences", the USA scores 21.97 in RLI_{Cik}, ranking 1st, far ahead of other countries/regions. The UK scores at 10.60, ranking 2nd. France and China register at 9.25 and 8.76, ranking 3rd and 4th, respectively. Germany scores 8.27, ranking 5th. As can be seen in Table 7, the USA and the UK rank in the same order according to all three indicators. France, China, and Germany's placements vary slightly according to the three measures.

Table 7. The score and rank of the Top 5 countries/regions based on RLI_{Cik}, $RFOI_{Cik}$ and $RFII_{Cik}$ in "Geosciences"

	Score					Rank				
Indicators	USA	UK	France	China	Germany	USA	UK	France	China	Germany
RLI_{Cik}	21.97	10.60	9.25	8.76	8.27	1	2	3	4	5
$RFOI_{Cik}$	11.19	5.27	4.48	4.78	3.80	1	2	4	3	5
$RFII_{Cik}$	10.77	5.32	4.77	3.98	4.47	1	2	3	6	4



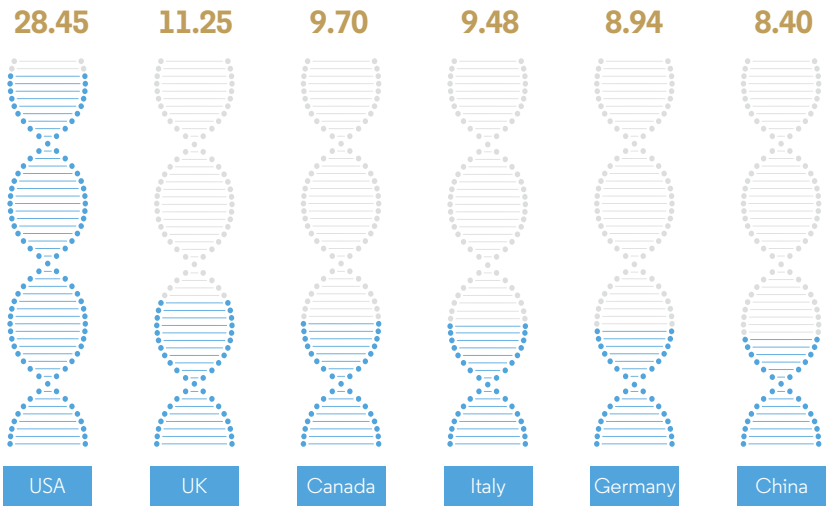
The score of RLI_{Cik}

3.4 CLINICAL MEDICINE: The USA far exceeds other countries/regions; the UK, Canada, Italy, and Germany rank 2nd to 5th; China has made significant progress, ranking 6th

In "Clinical medicine", the USA score 28.45 in RLI_{Cik}, ranking 1st, which is approximately 2.5 times higher second-ranked UK, and far ahead of other countries/regions. The UK registers at 11.25, less than half of the USA's score, ranking 2nd. Canada, Italy, and Germany score close to one another at 9.70, 9.48 and 8.94, ranking 3rd to 5th. China scores at 8.40, ranking 6th. The respective rankings of the USA and the UK in RLI_{Cik} are identical to those in $RFOI_{Cik}$ and $RFII_{Cik}$. Canada, Italy, Germany, and China's placements vary slightly according to the three indicators (Table 8).

Table 8. The score and rank of the Top 5 countries/regions + China based on RLI_{Cik}, $RFOI_{Cik}$ and $RFII_{Cik}$ in "Clinical medicine"

	Score						Rank					
Indicators	USA	UK	Canada	Italy	Germany	China	USA	UK	Canada	Italy	Germany	China
RLI_{Cik}	28.45	11.25	9.70	9.48	8.94	8.40	1	2	3	4	5	6
$RFOI_{Cik}$	14.35	5.19	4.15	4.90	3.99	4.84	1	2	5	3	6	4
$RFII_{Cik}$	14.10	6.06	5.55	4.58	4.95	3.56	1	2	3	5	4	9



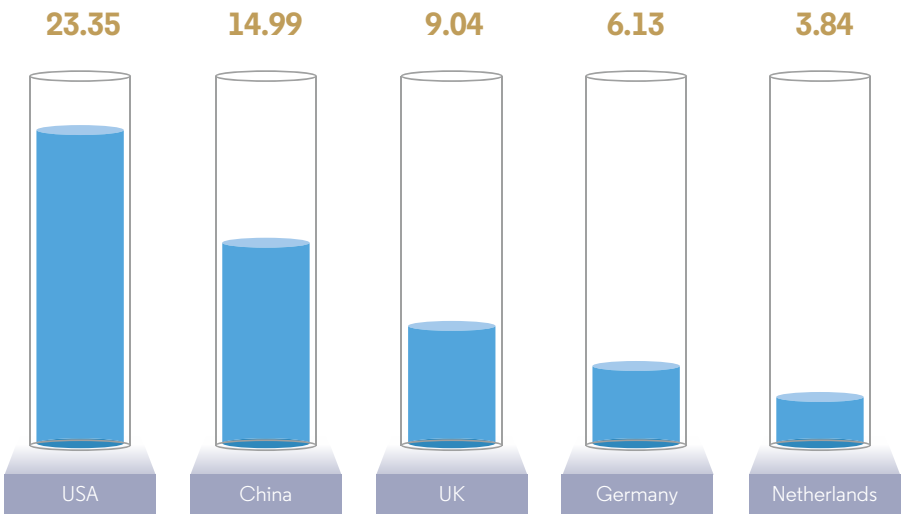
The score of RLI_{Cik}

3.5 BIOLOGICAL SCIENCES: The USA leads substantially; China has risen to 2nd

In "Biological sciences", the USA and China register respectively at 23.35 and 14.99 in RLI_{Cik}, placing 1st and 2nd, with their scores far exceeding those of other countries/regions. The UK registers at 9.04, ranking 3rd. Germany, and the Netherlands score 6.13 and 3.84 respectively, ranking 4th, and 5th. As can be seen in Table 9, the Top 5 countries rank in the same order according to all three indicators.

Table 9. The score and rank of the Top 5 countries/regions based on RLI_{Cik}, $RFOI_{Cik}$ and $RFII_{Cik}$ in the "Biological sciences"

	Score					Rank				
Indicators	USA	China	UK	Germany	Netherlands	USA	China	UK	Germany	Netherlands
RLI_{Cik}	23.35	14.99	9.04	6.13	3.84	1	2	3	4	5
$RFOI_{Cik}$	11.70	9.10	4.16	3.09	1.80	1	2	3	4	5
$RFII_{Cik}$	11.64	5.89	4.87	3.04	2.04	1	2	3	4	5



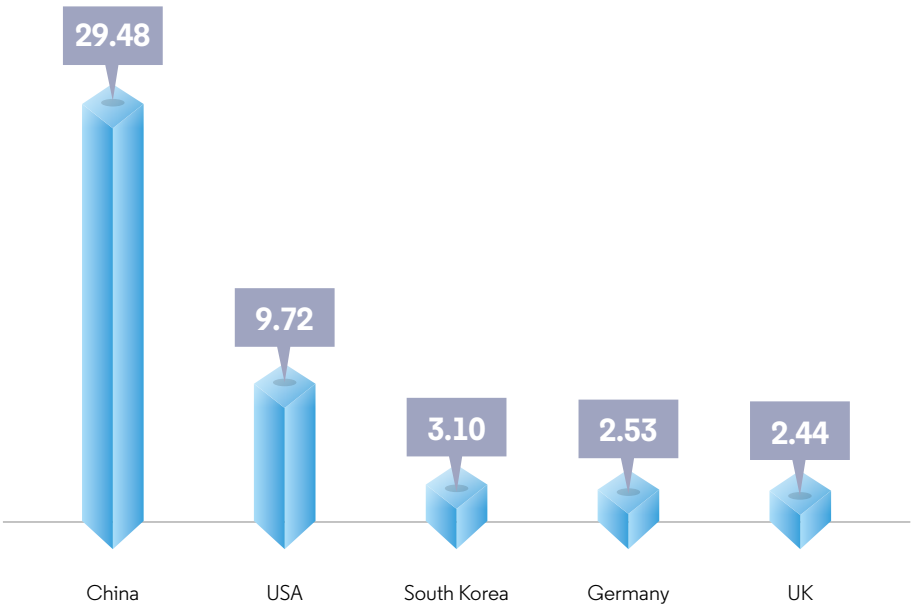
The score of RLI_{Cik}

3.6 CHEMISTRY AND MATERIALS SCIENCE: China's RLI_{Cik} demonstrates outstanding advantages; the USA is 2nd; South Korea maintains the third place

In "Chemistry and materials science", China's RLI_{Cik} mark is 29.48 and the overall advantage is obvious (Table 10). The USA scores 9.72, ranking 2nd. Although the USA lags China by a large margin, it still far exceeds other countries/regions. South Korea, Germany, and the UK post marks of 3.10, 2.53, and 2.44 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 South Korea, Germany, and the UK vary slightly among the three indicators.

Table 10. The score and rank of Top 5 countries/regions based on RLI_{Cik}, $RFOI_{Cik}$ and $RFII_{Cik}$ in "Chemistry and materials science"

	Score					Rank				
Indicators	China	USA	South Korea	Germany	UK	China	USA	South Korea	Germany	UK
RLI_{Cik}	29.48	9.72	3.10	2.53	2.44	1	2	3	4	5
$RFOI_{Cik}$	17.00	4.80	1.93	1.32	1.24	1	2	3	4	5
$RFII_{Cik}$	12.47	4.92	1.17	1.22	1.20	1	2	5	3	4



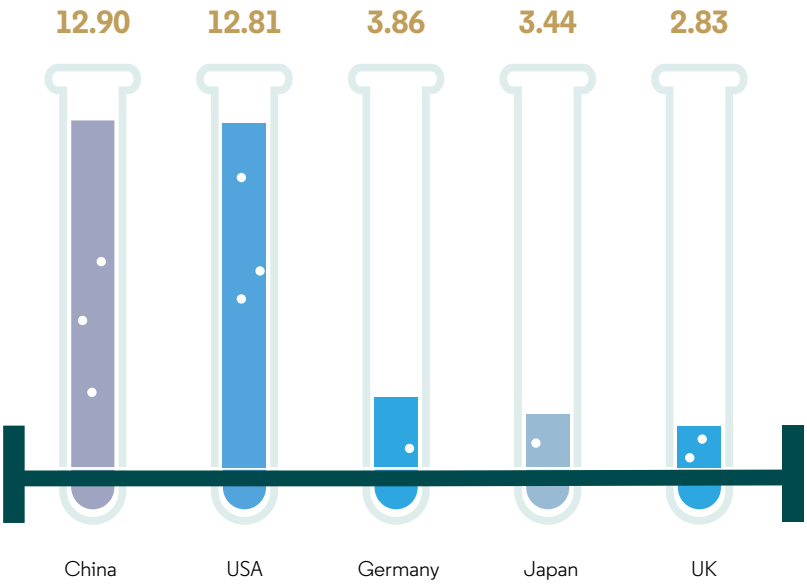
The score of RLI_{Cik}

3.7 PHYSICS: China and the USA run neck and neck; Germany, Japan, and the UK are 3rd to 5th

In "Physics", China and the USA's respective RLI_{Cik} scores of 12.90 and 12.81 lead to a ranking of 1st and 2nd. The difference in scores between the two countries is negligible. Germany and Japan score narrowly apart at 3.86 and 3.44, respectively. The UK scores 2.83, ranking 5th. China and the USA take turns leading in the three indicators (Table 11).

Table 11. The score and rank of the Top 5 countries/regions based on RLI_{Cik}, $RFOI_{Cik}$ and $RFII_{Cik}$ in "Physics"

	Score					Rank				
Indicators	China	USA	Germany	Japan	UK	China	USA	Germany	Japan	UK
RLI_{Cik}	12.90	12.81	3.86	3.44	2.83	1	2	3	4	5
$RFOI_{Cik}$	8.07	6.67	1.95	1.98	1.48	1	2	4	3	5
$RFII_{Cik}$	4.83	6.14	1.91	1.45	1.35	2	1	3	4	5



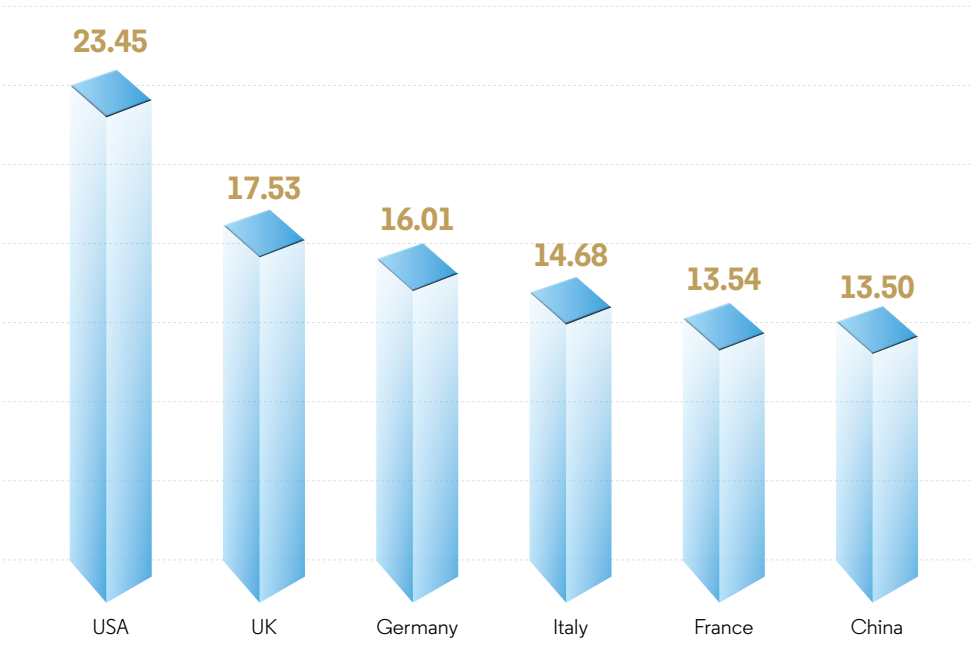
The score of RLI_{Cik}

3.8 ASTRONOMY AND ASTROPHYSICS: The USA has a dominant position; the UK, Germany, Italy, and France rank 2nd to 5th; China is 6th with the gap steadily narrowing

In "Astronomy and astrophysics" (Table 12), the USA ranks 1st, with an RLI_{Cik} score of 23.45. The UK ranks 2nd with a mark of 17.53, with Germany 3rd at 16.01, followed by Italy (14.68) and France (13.54). China places 6th with a score of 13.50. The top three countries/regions rank in the same order on the three indicators, while Italy, France, and China's placements vary according to the different measures.

Table 12. The score and rank of the Top 5 countries/regions + China based on RLI_{Cik}, $RFOI_{Cik}$ and $RFII_{Cik}$ in "Astronomy and astrophysics"

	Score						Rank					
Indicators	USA	UK	Germany	Italy	France	China	USA	UK	Germany	Italy	France	China
RLI_{Cik}	23.45	17.53	16.01	14.68	13.54	13.50	1	2	3	4	5	6
$RFOI_{Cik}$	12.33	8.74	8.07	7.33	6.19	6.90	1	2	3	4	6	5
$RFII_{Cik}$	11.12	8.79	7.95	7.35	7.35	6.60	1	2	3	5	4	7



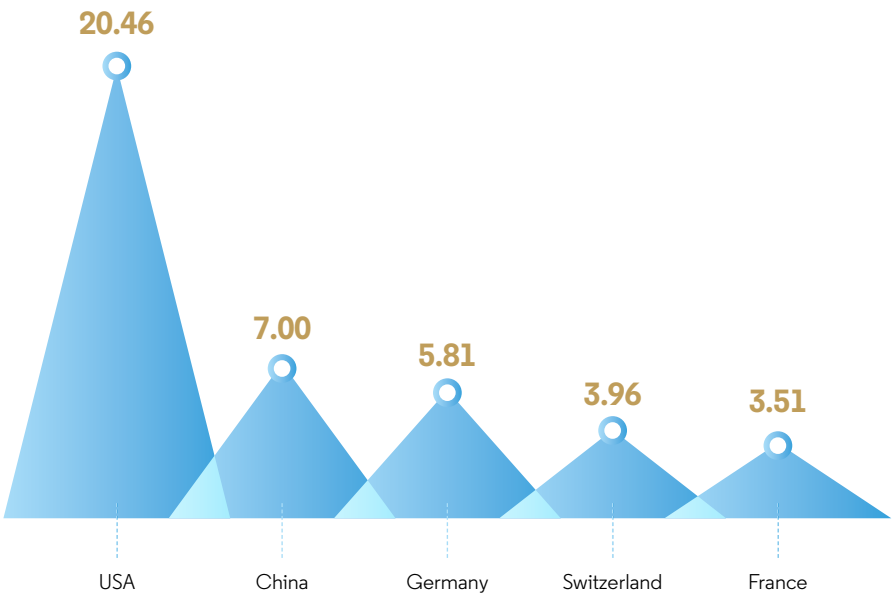
The score of RLI_{Cik}

3.9 MATHEMATICS: The USA scores far ahead of other countries; China ranks 2nd but still has a significant gap with the USA; Germany, Switzerland, and France are 3rd to 5th

In "Mathematics", the USA achieves the most active performance and ranks 1st, with a score of 20.46, leading with a significant advantage over other countries. Meanwhile, China posts a score of 7.00, ranking 2nd, but there is a significant gap compared to the USA. Germany and Switzerland score 5.81 and 3.96, respectively, ranking 3rd and 4th. France scores 3.51, ranking 5th. The rankings of the USA, Switzerland, and France according to the three indicators are completely consistent, while the rankings of China and Germany vary slightly among the three indicators (Table 13).

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

Indicators	Score					Rank				
	USA	China	Germany	Switzerland	France	USA	China	Germany	Switzerland	France
RLI_{Cik}	20.46	7.00	5.81	3.96	3.51	1	2	3	4	5
$RFOI_{Cik}$	10.48	4.28	2.78	1.92	1.87	1	2	3	4	5
$RFII_{Cik}$	9.98	2.72	3.03	2.04	1.64	1	3	2	4	5



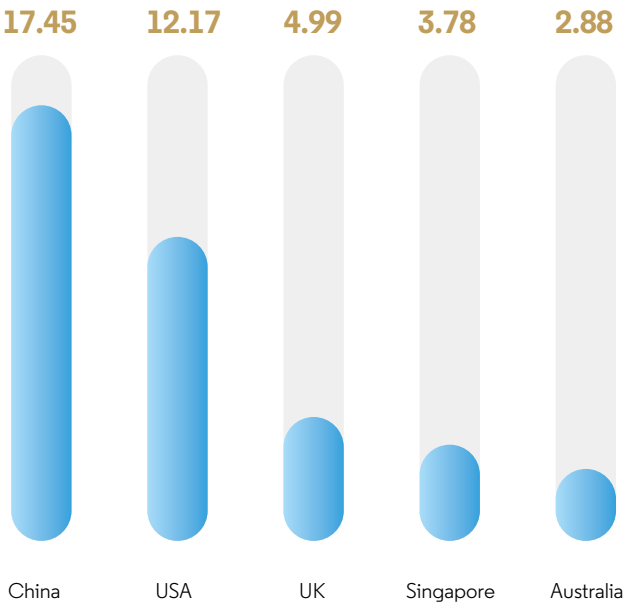
The score of RLI_{Cik}

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

In "Information science", China and the USA are the most active, with respective RLI_{Cik} scores of 17.45 and 12.17. The UK scores 4.99, ranking 3rd. Singapore and Australia score 3.78 and 2.88, ranking 4th to 5th, respectively. The rankings based on the three indicators for the top five countries/regions maintain complete consistency (Table 14).

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

	Score					Rank				
Indicators	China	USA	UK	Singapore	Australia	China	USA	UK	Singapore	Australia
RLI_{Cik}	17.45	12.17	4.99	3.78	2.88	1	2	3	4	5
$RFOI_{Cik}$	10.46	6.06	2.60	1.85	1.44	1	2	3	4	5
$RFII_{Cik}$	6.99	6.11	2.39	1.94	1.44	1	2	3	4	5



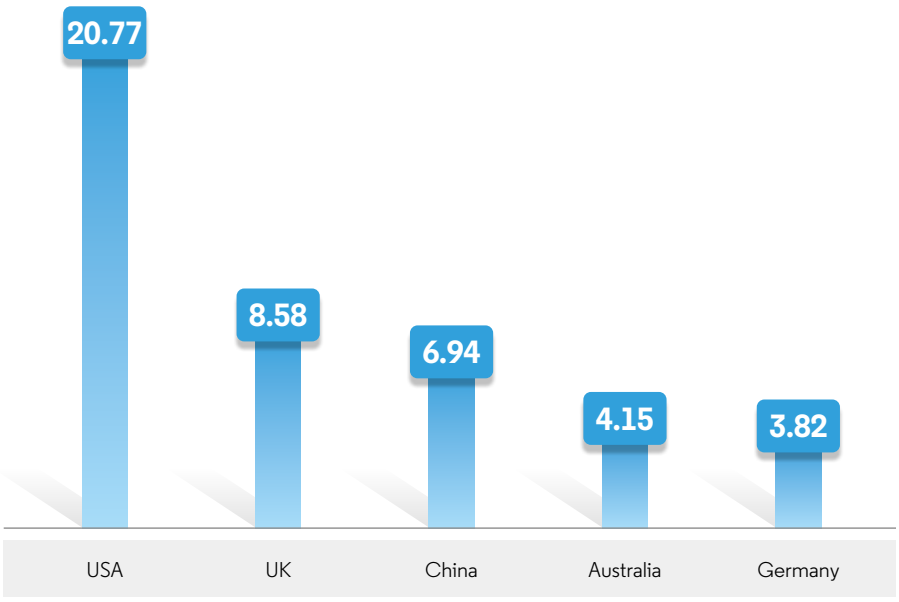
The score of RLI_{Cik}

3.11 ECONOMICS, PSYCHOLOGY AND OTHER SOCIAL SCIENCES: The USA holds firmly the top spot; The UK ranks 2nd; China, Australia, and Germany rank 3rd to 5th

In "Economics, psychology and other social sciences", the RLI_{Cik} score of the USA is 20.77, 2.4 times that of the second-ranked UK (8.58). China scores 6.94, ranking 3rd. Australia and Germany rank 4th and 5th with 4.15 and 3.82, respectively. For the Top 3 countries, 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 and Germany according to the three measures (Table 15).

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

	Score					Rank				
Indicators	USA	UK	China	Australia	Germany	USA	UK	China	Australia	Germany
RLI_{Cik}	20.77	8.58	6.94	4.15	3.82	1	2	3	4	5
$RFOI_{Cik}$	10.21	4.30	3.81	2.20	1.83	1	2	3	4	5
$RFII_{Cik}$	10.56	4.27	3.13	1.94	1.99	1	2	3	5	4



The score of RLI_{Cik}

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