



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



2023

Research Fronts: Active Fields, Leading Countries/Regions

Institutes of Science and Development,
Chinese Academy of Sciences

Clarivate



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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 2023” report is a prequel to another survey, “Research Fronts 2023: Active Fields, Leading Countries/Regions”, which selects and discusses 110 hot fronts and 18 emerging fronts in 11 broad research areas. Based on the findings of “Research Fronts 2023”, this second report uses the Research Leadership Index to assess the research activity of the world’s major countries/regions, to observe their performance in research output and impact, and to reveal a competitive landscape marked by intense rivalry.



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 each front’s 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 specialty areas.

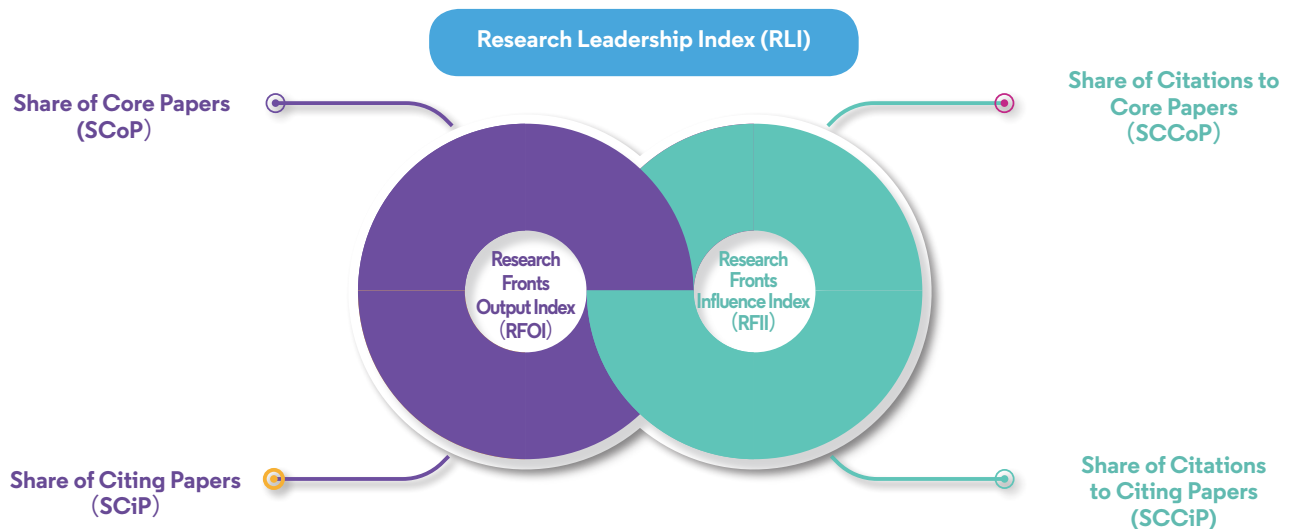


Figure 1. The logic model of Research Leadership Index (RLI)

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:

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

RFOI_{Cij} is the Research Fronts Output Index of a country/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}

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

A country/region's Share of Core Papers in a Research Front (SCoP_{Cij}) indicates the percentage of CoP_{ij} in CoP_j.

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

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.

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

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}.

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

Country/region'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/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.

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

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:

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

RLI_{Cik} is equal to the sum of the two indicators $RFOI_{Cik}$ and $RFII_{Cik}$.

(1) Research Fronts Output Index of a country/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 $SCiP_{Cik}$.

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

The formula for a country/region'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/region'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/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 $SCCiP_{Cik}$.

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

The formula for a country/region'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/region'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/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 128 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/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 128 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/region'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/region'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/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 128 Research Fronts. $RFII_{Ci}$ is equal to the sum of the two indicators $SCCoP_{Ci}$ and $SCCiP_{Ci}$.

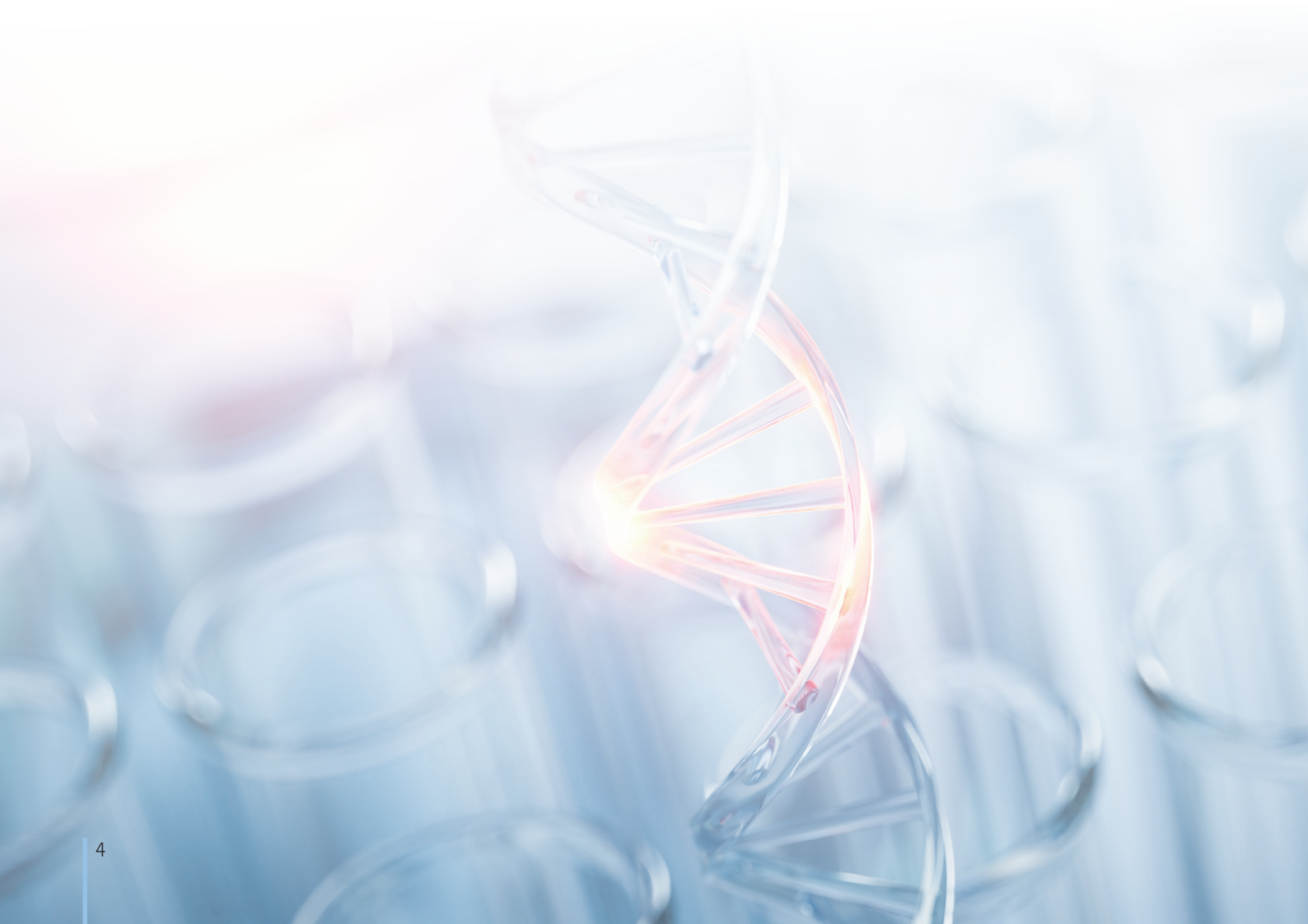
$$RFII_{Ci} = SCCoP_{Ci} + SCCiP_{Ci} = \sum_{k=1}^{10} \sum_{j=1}^n \frac{CoC_{ij}}{CoC_j} + \sum_{k=1}^{10} \sum_{j=1}^n \frac{CiC_{ij}}{CiC_j}$$

The formula for a country/region'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/region'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/Regions

We measured the RLI_{CI} of main countries/regions for overall performance in 11 broad research areas comprising 128 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 countries/regions of the USA and Chinese Mainland have solid positions, and the UK, Germany, and France rank 3rd to 5th

Based on 11 broad research areas and each country/region's respective performance in the 128 constituent Research Fronts, the USA is the most active, with an RLI_{CI} score of 207.71, ranking 1st (Figure 2). Chinese Mainland ranks 2nd with a score of 131.12. Both the USA and Chinese Mainland have a solid position, unmatched by any other countries/regions. The UK and Germany score 89.41 and 81.58, respectively, ranking 3rd and 4th in the second tier. France, which is in 5th

place, has a gap of at least 20 points with Germany.

The RLI_{CI} scores for Italy, Canada, Spain, Australia, and Japan register between 50 and 38, ranking those countries/regions from 6th to 10th, with Japan (at 38.65) ranking 10th. The Netherlands and Switzerland have scores close to those of Japan, but there is a gap of nearly ten points between them and South Korea.

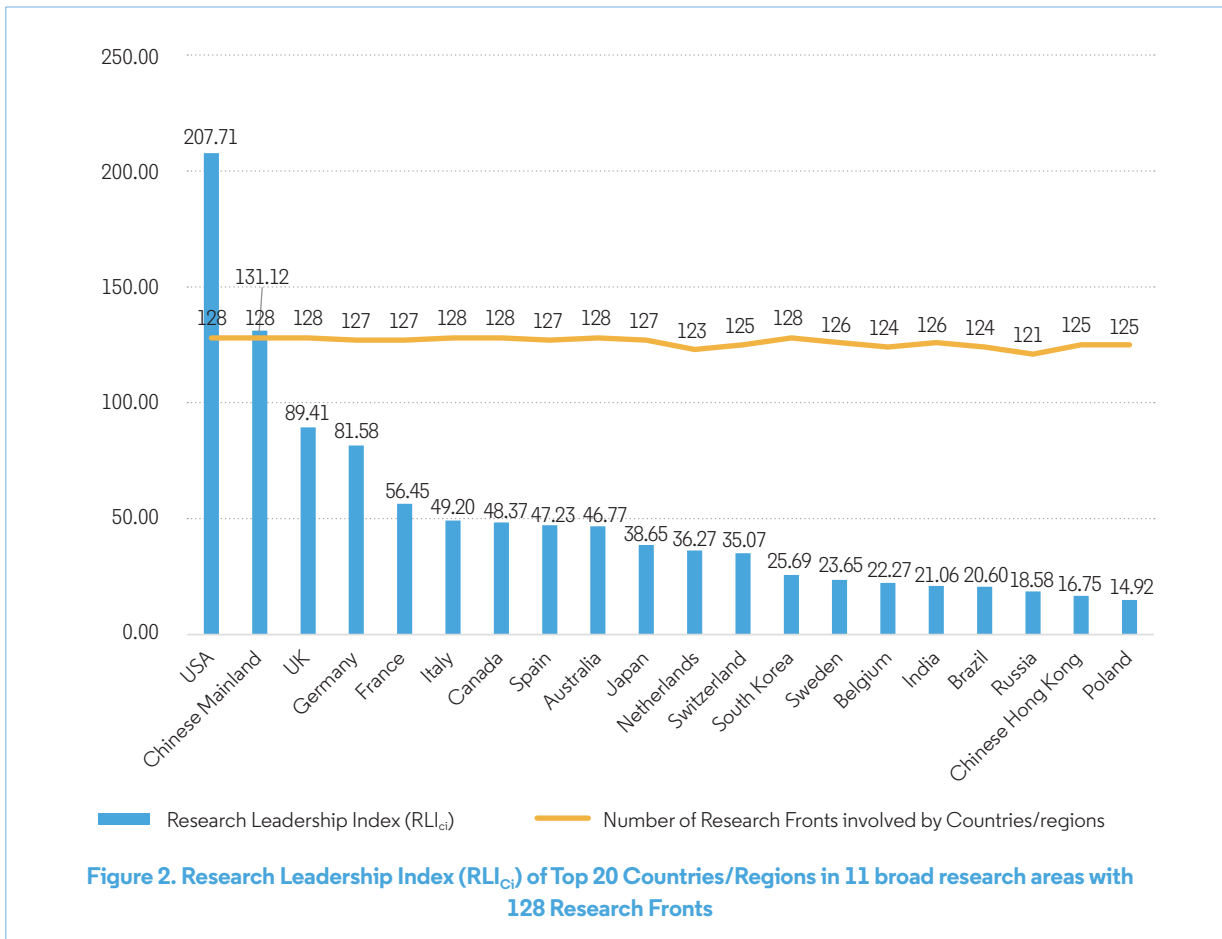


Table 1 shows that the rank order for the three indicators RLI_{Ci}, RFOI_{Ci}, and RFII_{Ci} for the top five countries/regions is

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 20th.

Table 1. The Research Leadership Index (RLI_{Ci}) of Top 20 Countries/regions in 11 broad research areas with 128 Research Fronts

	RLI _{Ci}		RFOI _{Ci}		RFII _{Ci}	
	Score	Rank	Score	Rank	Score	Rank
USA	207.71	1	106.88	1	100.83	1
Chinese Mainland	131.12	2	76.39	2	54.73	2
UK	89.41	3	44.81	3	44.60	3
Germany	81.58	4	41.01	4	40.57	4
France	56.45	5	27.08	5	29.37	5

	RLI _{Ci}		RFOI _{Ci}		RFII _{Ci}	
	Score	Rank	Score	Rank	Score	Rank
Italy	49.20	6	25.18	6	24.02	8
Canada	48.37	7	23.35	7	25.02	6
Spain	47.23	8	22.78	9	24.45	7
Australia	46.77	9	22.99	8	23.78	9
Japan	38.65	10	20.07	10	18.58	11
Netherlands	36.27	11	17.61	11	18.66	10
Switzerland	35.07	12	16.99	12	18.08	12
South Korea	25.69	13	12.93	13	12.76	13
Sweden	23.65	14	11.58	14	12.07	14
Belgium	22.27	15	10.77	16	11.50	15
India	21.06	16	11.39	15	9.67	17
Brazil	20.60	17	10.34	17	10.27	16
Russia	18.58	18	9.08	18	9.50	18
Chinese Hong Kong	16.75	19	8.82	19	7.93	19
Poland	14.92	20	7.75	20	7.17	22

2.2 The USA shows obvious strength in leading seven areas, while Chinese Mainland 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", "Physics", "Astronomy and astrophysics", and "Mathematics", and 2nd in the other four areas. The figures indicate that, overall, the USA is exceptionally active in basic research.

Chinese Mainland's RLI_{Ci} scores ranks 1st in four areas: "Agricultural, plant and animal sciences", "Ecology and environmental sciences", "Chemistry and materials science", and "Information science", Chinese Mainland ranks 2nd in three areas: "Physics", "Mathematics", and "Economics, psychology and other social sciences", 3rd in "Biological sciences", and 5th, 9th, and 8th in "Geosciences", "Clinical medicine", and

"Astronomy and astrophysics", respectively.

"Clinical medicine" and "Astronomy and astrophysics" have always been relatively weak areas for Chinese Mainland. From a historical perspective, we compare the changes in RLI_{Ci} in these two areas in the last seven years. From 2017 to 2023, Chinese Mainland ranked 10th, 13th, 9th, 12th, 1st, 4th, and 9th in terms of RLI_{Ci} in the area of "Clinical medicine", in which research on COVID-19 in 2021 and 2022 accounted for a large proportion, directly elevating Chinese Mainland's ranking in the area. But in 2023, Chinese Mainland's score returned to the level of 2019. Meanwhile, the region respectively ranked 11th, 19th, 11th, 8th, 8th, 7th, and 8th in "Astronomy and astrophysics" for the last seven years. From 2020 to 2023, the overall ranking remained around 8th place.

Table 2. The score and rank of RLI_{CI} and RLI_{CR} of Top20 Countries/Regions

Countries/ regions	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	207.71	1	10.89	2	12.48	2	23.79	1	33.72	1	25.52	1	14.18	2	17.98	1	21.96	1	23.46	1	12.08	2	11.66	1
Chinese Mainland	131.12	2	13.65	1	15.07	1	7.16	5	7.98	9	9.10	3	22.41	1	12.45	2	10.01	8	9.79	2	12.35	1	11.16	2
UK	89.41	3	3.67	5	8.35	3	10.69	2	11.57	5	14.39	2	2.83	4	6.01	5	15.54	3	2.00	5	4.93	3	9.42	3
Germany	81.58	4	4.30	3	6.68	4	8.20	4	14.90	2	8.14	4	2.81	5	8.20	3	18.98	2	2.82	4	2.03	9	4.53	4
France	56.45	5	3.85	4	2.81	10	8.62	3	12.22	4	4.19	11	1.52	9	3.85	8	12.19	5	1.22	8	2.76	5	3.23	6
Italy	49.20	6	2.09	10	3.02	8	4.36	10	9.89	7	6.29	7	1.07	16	4.43	7	12.94	4	0.76	9	1.13	13	3.22	7
Canada	48.37	7	2.44	8	4.61	7	6.57	7	10.01	6	5.06	9	2.70	6	1.89	16	8.72	10	1.40	7	2.66	6	2.31	13
Spain	47.23	8	2.15	9	1.51	17	4.18	11	13.16	3	5.58	8	0.58	20	3.64	9	12.15	6	0.69	11	1.28	12	2.32	12
Australia	46.77	9	3.42	6	5.28	6	6.94	6	7.50	10	6.65	5	1.91	8	1.56	19	6.95	11	0.75	10	1.67	10	4.15	5
Japan	38.65	10	0.99	19	2.09	12	5.09	8	6.33	12	3.13	16	2.43	7	7.11	4	9.25	9	0.39	16	0.88	16	0.95	29
Netherlands	36.27	11	1.53	15	6.38	5	4.67	9	3.88	16	3.42	13	1.11	15	1.28	29	11.18	7	0.50	13	0.62	18	1.70	17
Switzerland	35.07	12	1.58	14	2.92	9	3.84	12	4.34	13	4.16	12	0.30	25	5.34	6	6.48	12	1.96	6	1.10	14	3.05	8
South Korea	25.69	13	0.77	22	0.86	23	1.61	18	2.04	22	4.24	10	3.22	3	3.17	10	5.75	15	0.29	19	2.37	7	1.36	24
Sweden	23.65	14	0.52	28	2.33	11	1.70	17	1.70	27	6.51	6	0.34	22	1.51	21	6.25	13	0.44	14	0.40	25	1.95	16
Belgium	22.27	15	0.49	30	1.59	16	2.00	14	6.37	11	3.18	14	0.39	21	1.59	18	4.70	20	0.22	24	0.27	27	1.47	22
India	21.06	16	1.95	11	1.08	21	1.11	21	1.32	31	2.48	21	1.27	11	2.64	12	5.68	16	0.21	25	0.50	22	2.84	10
Brazil	20.60	17	1.53	16	1.11	20	0.39	30	8.67	8	2.12	23	0.13	32	1.41	24	3.94	23	0.23	23	0.11	38	0.96	28
Russia	18.58	18	0.66	23	0.75	26	0.55	28	2.92	18	2.93	17	0.32	23	3.05	11	5.64	17	0.18	29	0.21	33	1.37	23
Chinese Hong Kong	16.75	19	0.15	46	1.41	18	0.23	33	0.25	48	2.18	22	1.21	12	0.56	54	4.88	19	3.17	3	1.03	15	1.68	18
Poland	14.92	20	0.45	32	0.71	28	0.22	34	4.16	14	1.96	26	0.14	31	2.12	14	3.87	24	0.14	33	0.21	32	0.93	30

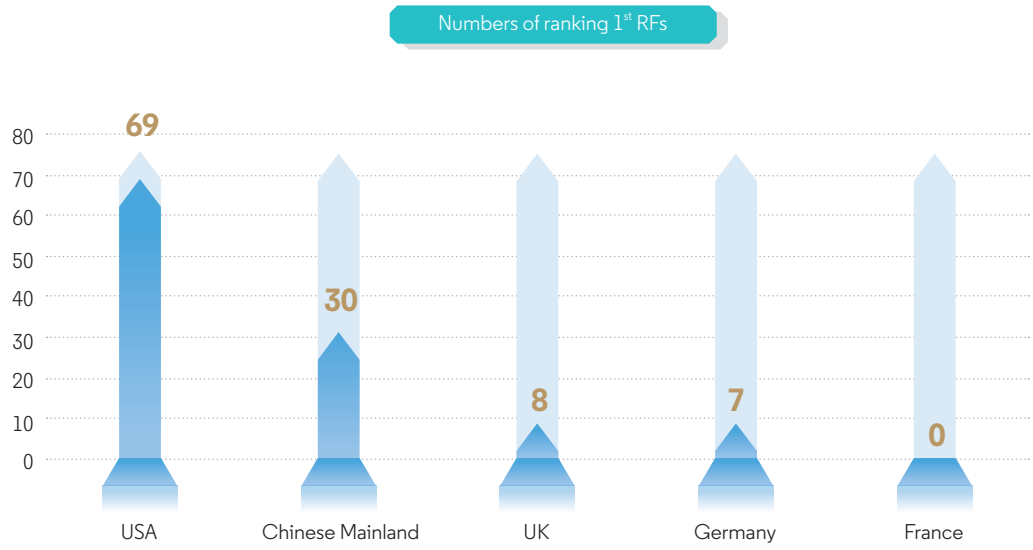
Among the 110 hot Research Fronts and 18 emerging Research Fronts in 11 broad research areas, the USA ranks 1st in 69, accounting for 53.91% of the 128 Research Fronts. Chinese Mainland earns the top spot in 30 fronts, or 23.44%. The UK is tops in eight Research Fronts, Germany ranks 1st in seven, while France does not have a leading front ranking 1st (Table 3).

Of the 11 broad research areas, there are eight fronts within “Chemistry and materials science” in which Chinese Mainland ranks 1st, compared to only three for the USA. In the areas of “Agricultural, plant and animal sciences” and “Economics, psychology and other social sciences”, the number of fronts

in which Chinese Mainland ranks 1st slightly exceeds that of the USA. In the area of “Ecology and environmental sciences”, the two countries/regions are actually tied in terms of the number of fronts in which they rank 1st. In the five areas of “Biological sciences”, “Physics”, “Astronomy and astrophysics”, “Mathematics”, and “Information science”, the numbers of fronts in which Chinese Mainland ranks 1st are all less than those of the USA. In the fields of “Geosciences” and “Clinical medicine”, Chinese Mainland does not hold the top position, while the USA has at least 70% of the fronts ranking 1st, leaving a huge gap between the two countries/regions in these areas (Table 3).

Table 3. The numbers and ratios of the Research Fronts in which the respective Top 5 countries/regions rank first, out of 128 fronts in 11 broad research areas (based on RLI_C)

Areas	Numbers of RFs	Numbers of ranking 1 st RFs					Ratios				
		USA	Chinese Mainland	UK	Germany	France	USA	Chinese Mainland	UK	Germany	France
11 broad research areas total	128	69	30	8	7	0	53.91%	23.44%	6.25%	5.47%	0.00%
Agricultural, plant and animal sciences	11	4	5	0	0	0	36.36%	45.45%	0.00%	0.00%	0.00%
Ecology and environmental sciences	11	4	4	1	1	0	36.36%	36.36%	9.09%	9.09%	0.00%
Geosciences	11	10	0	0	0	0	90.91%	0.00%	0.00%	0.00%	0.00%
Clinical medicine	15	11	0	1	2	0	73.33%	0.00%	6.67%	13.33%	0.00%
Biological sciences	14	9	1	1	0	0	64.29%	7.14%	7.14%	0.00%	0.00%
Chemistry and materials science	12	3	8	0	1	0	25.00%	66.67%	0.00%	8.33%	0.00%
Physics	11	9	2	0	0	0	81.82%	18.18%	0.00%	0.00%	0.00%
Astronomy and astrophysics	12	6	2	2	2	0	50.00%	16.67%	16.67%	16.67%	0.00%
Mathematics	10	7	2	0	0	0	70.00%	20.00%	0.00%	0.00%	0.00%
Information science	10	4	3	1	0	0	40.00%	30.00%	10.00%	0.00%	0.00%
Economics, psychology and other social sciences	11	2	3	2	1	0	18.18%	27.27%	18.18%	9.09%	0.00%



Among countries/regions ranking among the top three performers in the 128 Research Fronts (Table 4), the USA earns that distinction in 105 fronts, or 82.03%, Chinese Mainland in 67 Research Fronts (52.34%), the UK in 42, Germany in 39,

and France in 14, with the latter three countries/regions able to respectively boast the achievement in 32.81%, 30.47% and 10.94% of the total number of Research Fronts.

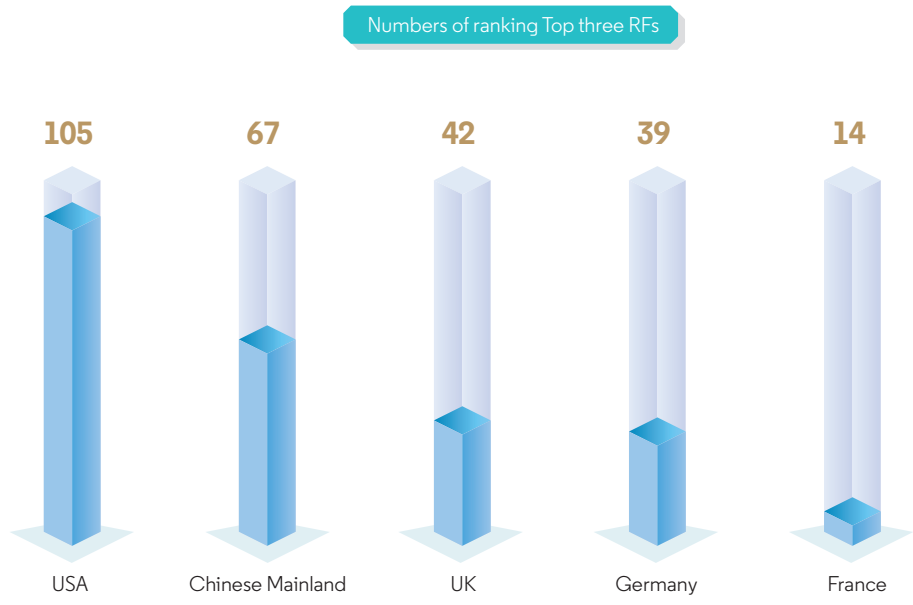
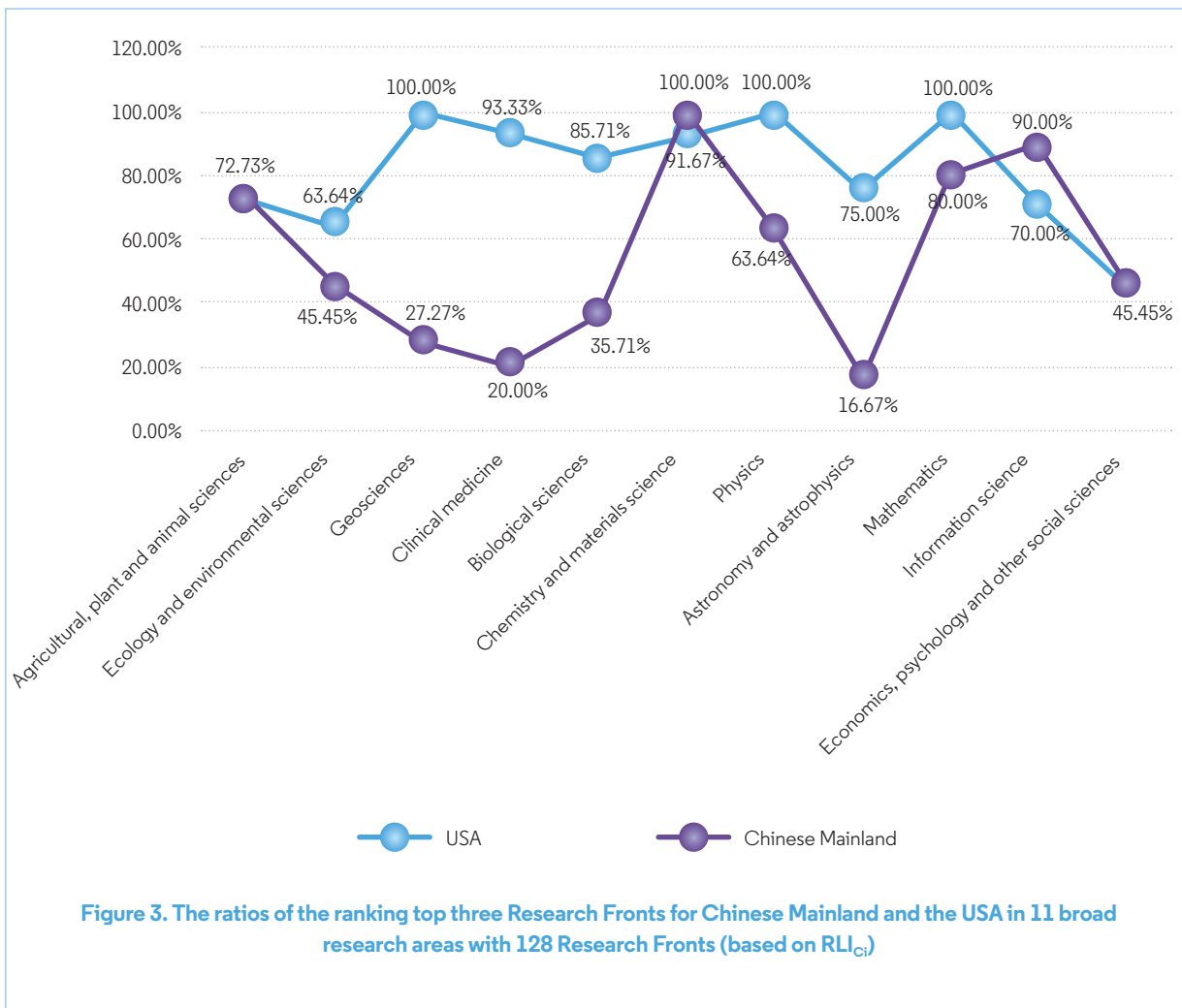


Table 4. The numbers and ratios of countries/regions ranking among the top three performers in Research Fronts, among the Top 5 countries/regions in 11 broad research areas with 128 Research Fronts (based on RLI_{CI})

Areas	Numbers of RFs	Numbers of ranking Top three RFs					Ratios				
		USA	Chinese Mainland	UK	Germany	France	USA	Chinese Mainland	UK	Germany	France
11 broad research areas total	128	105	67	42	39	14	82.03%	52.34%	32.81%	30.47%	10.94%
Agricultural, plant and animal sciences	11	8	8	1	2	2	72.73%	72.73%	9.09%	18.18%	18.18%
Ecology and environmental sciences	11	7	5	6	5	0	63.64%	45.45%	54.55%	45.45%	0.00%
Geosciences	11	11	3	5	2	3	100.00%	27.27%	45.45%	18.18%	27.27%
Clinical medicine	15	14	3	4	3	2	93.33%	20.00%	26.67%	20.00%	13.33%
Biological sciences	14	12	5	7	2	1	85.71%	35.71%	50.00%	14.29%	7.14%
Chemistry and materials science	12	11	12	0	3	0	91.67%	100.00%	0.00%	25.00%	0.00%
Physics	11	11	7	3	6	0	100.00%	63.64%	27.27%	54.55%	0.00%
Astronomy and astrophysics	12	9	2	6	9	2	75.00%	16.67%	50.00%	75.00%	16.67%
Mathematics	10	10	8	4	3	1	100.00%	80.00%	40.00%	30.00%	10.00%
Information science	10	7	9	2	1	2	70.00%	90.00%	20.00%	10.00%	20.00%
Economics, psychology and other social sciences	11	5	5	4	3	1	45.45%	45.45%	36.36%	27.27%	9.09%

The USA makes the top three in more than 45% of the respective Research Fronts associated with each of the 11 broad research areas. In the three areas of “Physics”, “Mathematics”, and “Geosciences”, the USA ranks among the top three performers in 100% of the pertinent Research Fronts. This notably superior performance also carries over into “Chemistry and materials science” and “Clinical medicine”, in which the USA ranks among the top three in 91.67% and 93.33%. The lowest proportion for the USA is in the area of “Economics, psychology and other social sciences”, accounting for 45.45%. In the other five areas, meanwhile, the USA’s proportions of top three account range from 63.64% to 85.71%.

Chinese Mainland’s proportion of top-three placements ratio reaches more than 45% in seven major specialty areas, of which the highest proportion is in “Chemistry and material science”, “Information science”, “Agricultural, plant and animal sciences”, and “Mathematics”, accounting for 100%, 90%, 72.73% and 80%, respectively. Chinese Mainland registers among the top three in the range of 63.64% in “Physics”. In the areas of “Economics, psychology and other social sciences” and “Ecology and environmental sciences”, the proportion of top-three placements ratio both register at 45.45%. Chinese Mainland’s ratio of top three fronts in the four areas of “Biological sciences”, “Geosciences”, “Clinical medicine”, and “Astronomy and astrophysics” is 35.71%, 27.27%, 20%, and 16.67%.



The percentage of UK’s top three Research Fronts in the 11 areas are all below 55%, registering among the top three by proportions ranging from 45.45% to 54.55% of the Research Fronts in four broad specialty areas: “Economics, psychology and other social sciences”, “Biological sciences”, “Astronomy and astrophysics”, and “Geosciences”. In the other six areas, the UK’s presence in the top three ranges from 9.09% to 40% of Research Fronts. The UK, however, does not rank in the top three in the area of “Chemistry and materials science”.

Germany has its highest proportion of top three Research Fronts in the area of “Astronomy and astrophysics”, accounting for 75%, representing the nation’s dominant performance.

In the areas of “Physics” and “Ecology and environmental sciences”, the proportion of top-three placements ratio register at 54.55% and 45.45%. In the other eight areas, the proportion of leading positions in which Germany ranks among the top three ranges between 10% to 30%.

In the field of “Geosciences” and “Information science”, France holds proportions of 27.27% and 20%, respectively, in Research Fronts ranking in the top three. In the other seven fields, the proportion ranges between 7.14% and 18.18%. There are no fronts ranking in the top three in the fields of “Agricultural, plant and animal sciences”, “Chemistry and materials science”, as well as “Physics”.

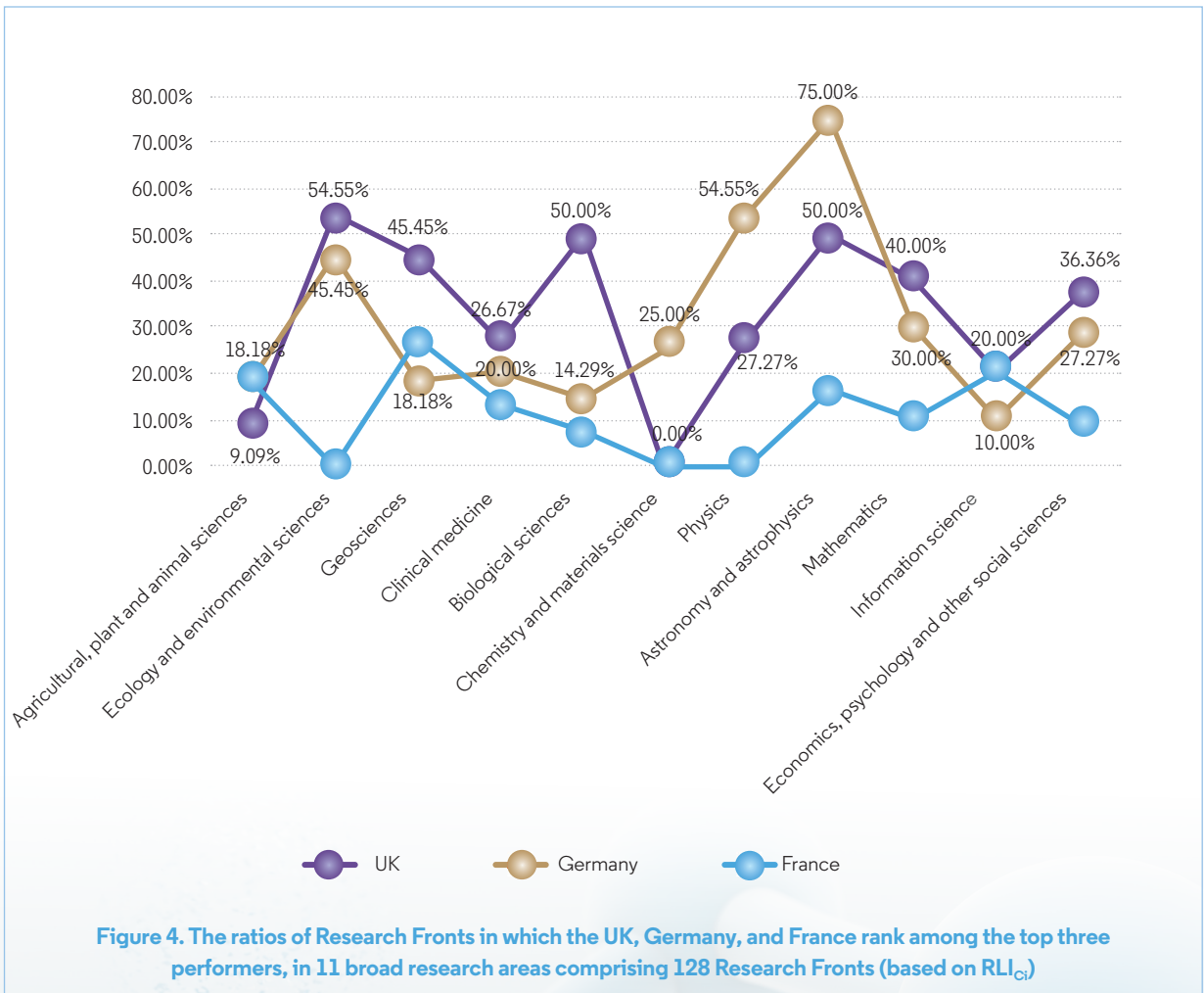


Figure 4. The ratios of Research Fronts in which the UK, Germany, and France rank among the top three performers, in 11 broad research areas comprising 128 Research Fronts (based on RLI_{Ci})

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 vitality of countries/regions in scientific and technical innovation.

3.1 AGRICULTURAL, PLANT AND ANIMAL SCIENCES: Chinese Mainland has an obvious advantage; the USA is 2nd; Germany, France, and the UK are the 3rd to 5th

In the area of “Agricultural, plant and animal sciences”, Chinese Mainland is the most active according to its RLI_{Cik} score of 13.65, ranking 1st (Table 5). The USA scores 10.89, ranking 2nd. Germany scores 4.30, ranking 3rd. France and the UK 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 Chinese Mainland and the USA. By contrast, the rankings for Germany, France, and the UK vary slightly according to the three indicators.

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

Indicators	Score					Rank				
	Chinese Mainland	USA	Germany	France	UK	Chinese Mainland	USA	Germany	France	UK
RLI_{Cik}	13.65	10.89	4.30	3.85	3.67	1	2	3	4	5
$RFOI_{Cik}$	7.87	5.63	2.33	1.73	1.63	1	2	3	4	6
$RFII_{Cik}$	5.78	5.26	1.97	2.12	2.04	1	2	5	3	4



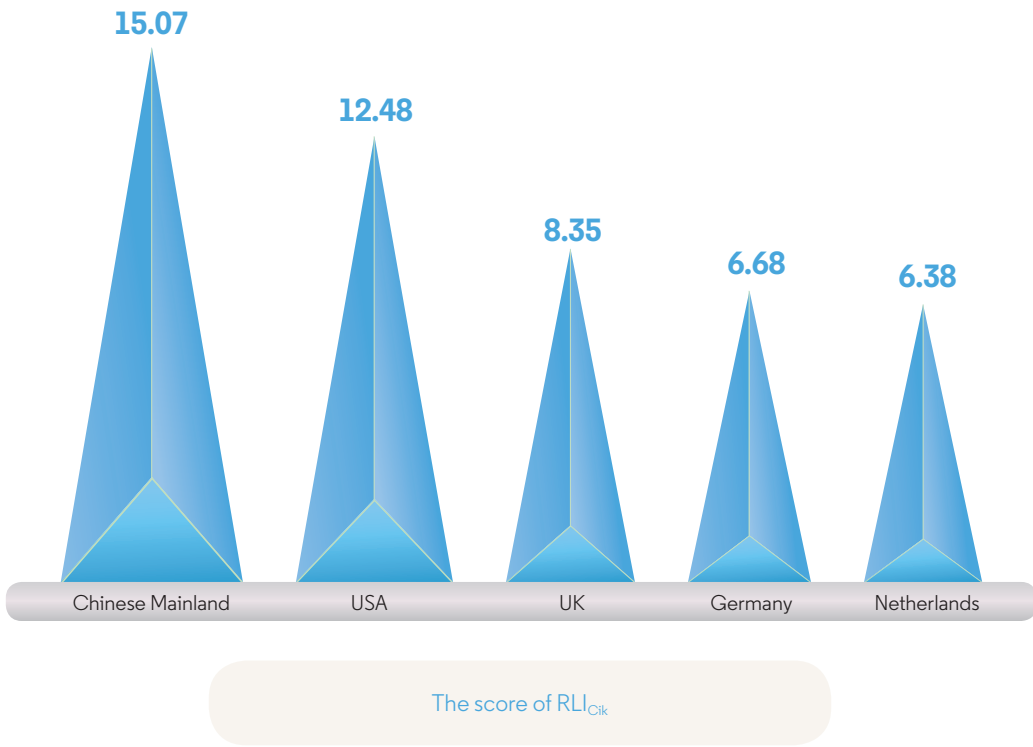
3.2 ECOLOGY AND ENVIRONMENTAL SCIENCES: Chinese Mainland leads; the USA is 2nd; the UK, Germany, and the Netherlands rank 3rd to 5th

In the area of “Ecology and environmental sciences” (Table 6), Chinese Mainland scores 15.07 in RLI_{Cik} , ranking 1st, demonstrating the most activity. The USA scores 12.48, ranking 2nd. The UK scores 8.35, ranking 3th. Germany and the

Netherlands are in 4th and 5th place, with respective scores of 6.68 and 6.38. The rank order of the Top 5 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 the area of “Ecology and environmental sciences”

Indicators	Score					Rank				
	Chinese Mainland	USA	UK	Germany	Netherlands	Chinese Mainland	USA	UK	Germany	Netherlands
RLI_{Cik}	15.07	12.48	8.35	6.68	6.38	1	2	3	4	5
$RFOI_{Cik}$	8.14	6.52	4.23	3.02	2.74	1	2	3	4	5
$RFII_{Cik}$	6.92	5.96	4.12	3.66	3.64	1	2	3	4	5



3.3 Geosciences: The USA ranks 1st; the UK is 2nd; France and Germany are equally accomplished, and Chinese Mainland ranks 5th

In the area of “Geosciences”, the USA scores 23.79 in RLI_{Cik} , ranking 1st, far ahead of other countries/regions. The UK scores 10.69, ranking 2nd. France and Germany register at 8.62 and 8.20, ranking 3rd and 4th, respectively. Chinese Mainland scores

7.16, ranking 5th. As can be seen in Table 8, the USA, and the UK rank in the same order according to all three indicators. The placements of France, Germany and Chinese Mainland vary slightly according to the three indicators.

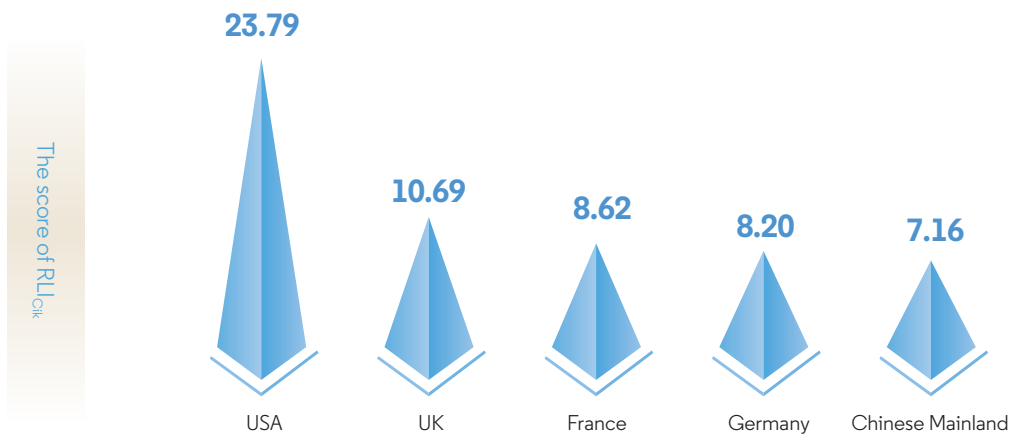


Table 7. The score and rank of the Top 5 countries/regions based on RLI_{Cik} , $RFOI_{Cik}$ and $RFII_{Cik}$ in the area of “Geosciences”

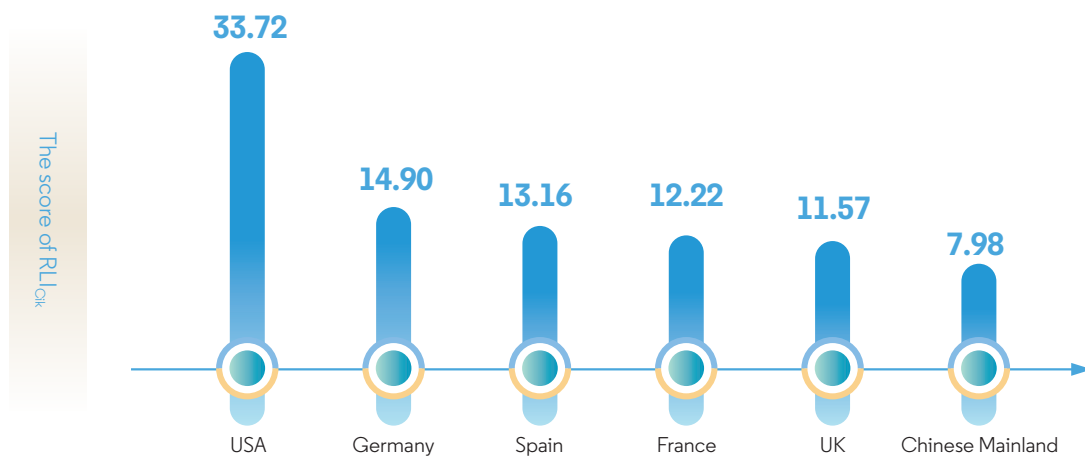
Indicators	Score					Rank				
	USA	UK	France	Germany	Chinese Mainland	USA	UK	France	Germany	Chinese Mainland
RLI_{Cik}	23.79	10.69	8.62	8.20	7.16	1	2	3	4	5
$RFOI_{Cik}$	12.21	5.42	4.42	4.22	4.46	1	2	4	5	3
$RFII_{Cik}$	11.59	5.27	4.20	3.98	2.70	1	2	3	4	7

3.4 CLINICAL MEDICINE: The USA far exceeds other countries/regions, Germany is 2nd; Spain, France, and the UK have close scores, Chinese Mainland ranks 9th

In the area of “Clinical medicine”, the USA score 33.72 in RLI_{Cik} , ranking 1st, far ahead of other countries/regions. Germany registers at 14.90, less than half of the USA, ranking 2nd. Spain, France, and the UK score close to one another at 13.16, 12.22 and 11.57, ranking 3rd to 5th. Chinese Mainland scores at 7.98, ranking 9th. The USA ranks first in all three indicators. Chinese Mainland’s placements vary slightly according to the three indicators.

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

Indicators	Score						Rank					
	USA	Germany	Spain	France	UK	Chinese Mainland	USA	Germany	Spain	France	UK	Chinese Mainland
RLI_{Cik}	33.72	14.90	13.16	12.22	11.57	7.98	1	2	3	4	5	9
$RFOI_{Cik}$	16.87	6.67	5.79	5.33	5.42	4.35	1	2	3	5	4	8
$RFII_{Cik}$	16.85	8.23	7.37	6.88	6.15	3.62	1	2	3	4	5	10



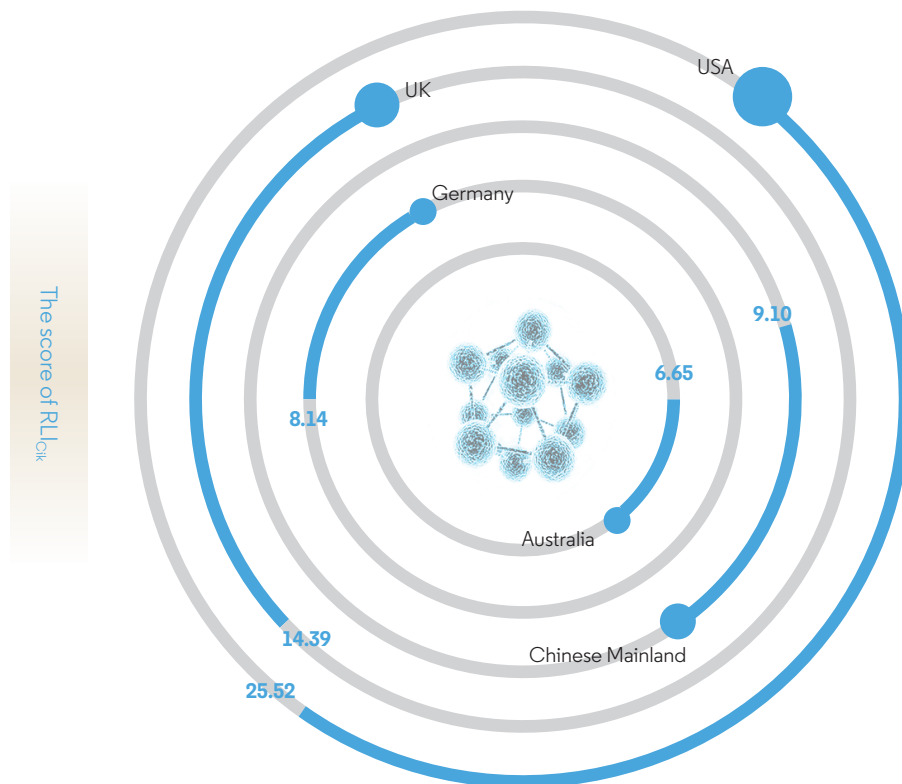
3.5 BIOLOGICAL SCIENCES: The USA leads substantially, the UK is 2nd, while Chinese Mainland, Germany, and Australia rank 3rd to 5th

In the area of “Biological sciences”, the USA and the UK register at 25.52 and 14.39 in RLI_{Cik} , placing 1st and 2nd, with scores far exceeding those of other countries/regions. Chinese Mainland scores 9.10, ranking 3rd. Germany, and Australia score 8.14 and 6.65 respectively, ranking 4th, and 5th. As can be seen in Table

9, the USA, and the UK rank in the same order according to all three indicators, contrasting with the varying placements by Chinese Mainland, Germany, and Australia according to the three measures.

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

Indicators	Score					Rank				
	USA	UK	Chinese Mainland	Germany	Australia	USA	UK	Chinese Mainland	Germany	Australia
RLI_{Cik}	25.52	14.39	9.10	8.14	6.65	1	2	3	4	5
$RFOI_{Cik}$	13.08	7.00	5.93	4.30	3.17	1	2	3	4	6
$RFII_{Cik}$	12.44	7.39	3.16	3.84	3.48	1	2	6	3	4



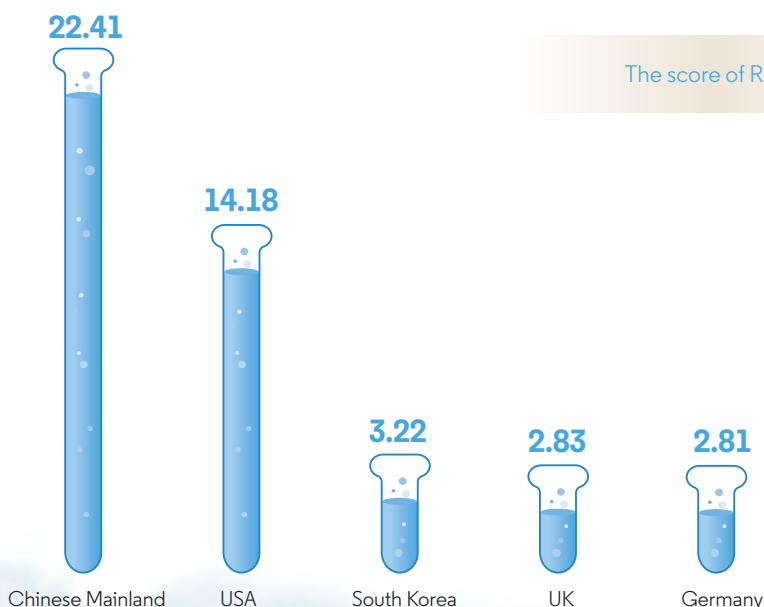
3.6 CHEMISTRY AND MATERIALS SCIENCE: Chinese Mainland’s RLI_{Cik} demonstrates outstanding advantages; the USA is 2nd, South Korea, the UK, and Germany rank 3rd to 5th

In the area of “Chemistry and materials science”, Chinese Mainland’s RLI_{Cik} score is 22.41, earning Chinese Mainland 1st place (Table 10). The USA scores 14.18, ranking 2nd. These scores indicate a significant activity gap between Chinese Mainland and the USA in this area. Although the USA lags Chinese Mainland by a large margin, it still far exceeds other

countries/regions. South Korea, the UK, and Germany post marks of 3.22, 2.83, and 2.81 respectively, ranking 3rd to 5th. The rankings based on the indicators RLI_{Cik} , $RFOI_{Cik}$, and $RFII_{Cik}$ for Chinese Mainland and the USA are the same, with Chinese Mainland ranking 1st and the USA 2nd.

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

Indicators	Score					Rank				
	Chinese Mainland	USA	South Korea	UK	Germany	Chinese Mainland	USA	South Korea	UK	Germany
RLI_{Cik}	22.41	14.18	3.22	2.83	2.81	1	2	3	4	5
$RFOI_{Cik}$	12.69	6.75	1.85	1.33	1.56	1	2	3	6	4
$RFII_{Cik}$	9.72	7.42	1.37	1.50	1.25	1	2	5	3	6



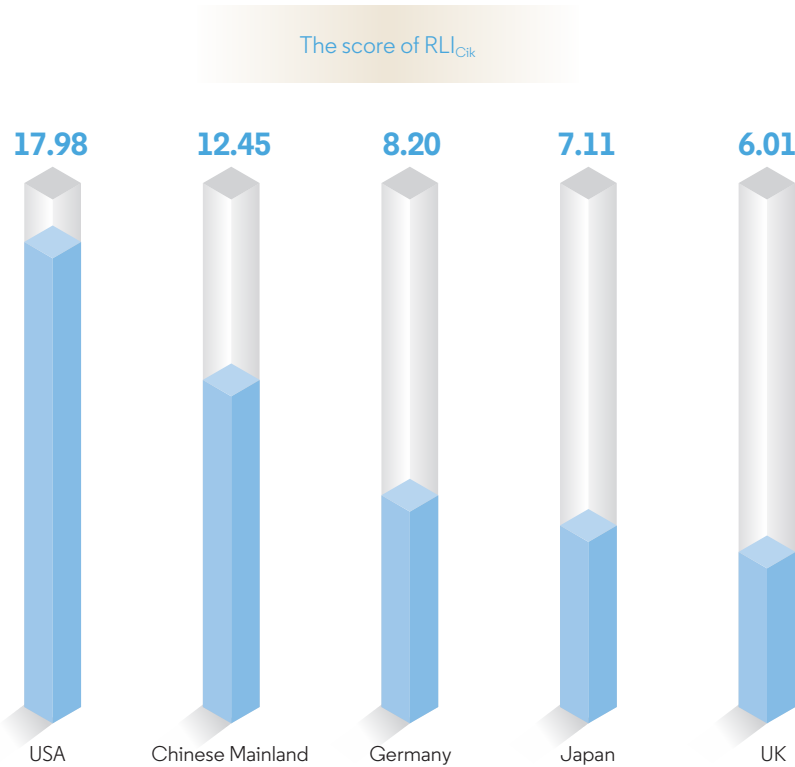
3.7 PHYSICS: The USA ranks 1st; Chinese Mainland is 2nd; Germany, Japan, and the UK are 3rd to 5th

In the area of “Physics”, the USA posts the highest degree of activity with an RLI_{Cik} of 17.98, and Chinese Mainland scores 12.45, ranking 2nd. Chinese Mainland and the USA show an overall leading trend, while Germany and Japan score close at

8.20 and 7.11, respectively. The UK scores 6.01, ranking in 5th place. The top five countries/regions maintain the same rank order according to the three indicators.

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

Indicators	Score					Rank				
	USA	Chinese Mainland	Germany	Japan	UK	USA	Chinese Mainland	Germany	Japan	UK
RLI_{Cik}	17.98	12.45	8.20	7.11	6.01	1	2	3	4	5
$RFOI_{Cik}$	9.74	7.69	4.51	3.67	3.19	1	2	3	4	5
$RFII_{Cik}$	8.23	4.76	3.69	3.44	2.83	1	2	3	4	5



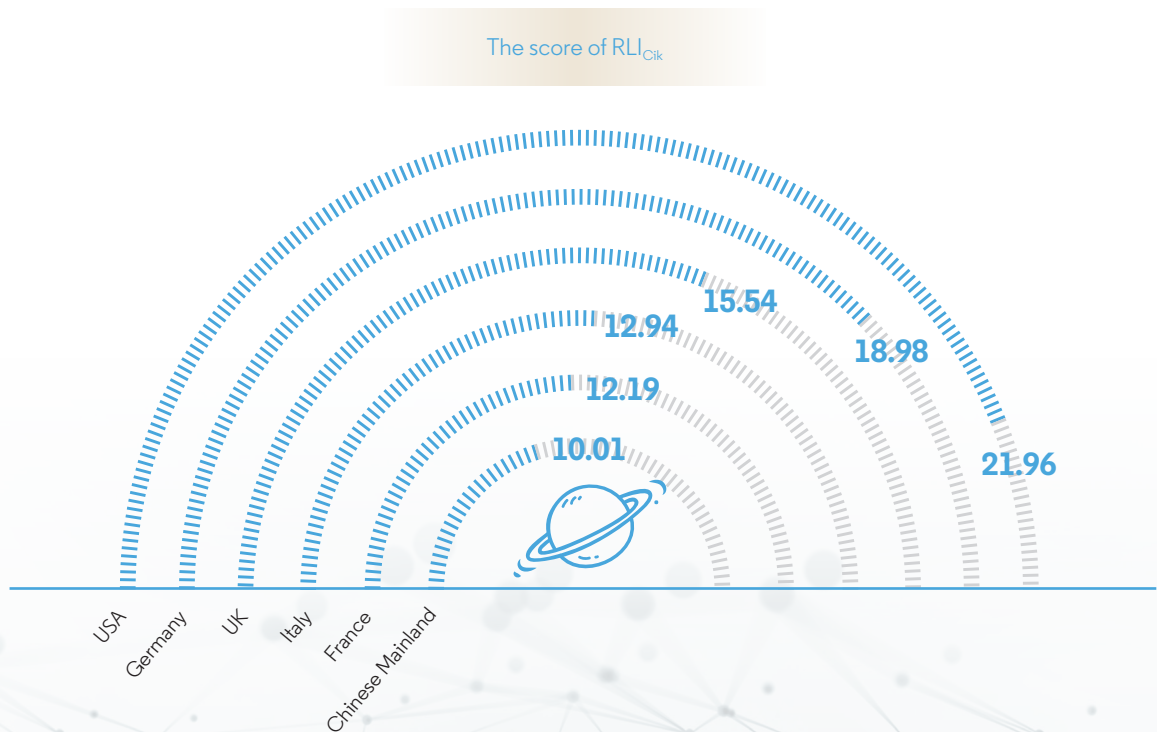
3.8 ASTRONOMY AND ASTROPHYSICS: The USA, Germany, and the UK rank in the top 3; Italy, and France rank 4th and 5th; Chinese Mainland is 8th

In the area of “Astronomy and astrophysics” (Table 12), the USA ranks 1st, with an RLI_{Cik} score of 21.96. Germany ranks 2nd with a mark of 18.98, with the UK 3rd at 15.54, followed by Italy (12.94) and France (12.19). Chinese Mainland places 8th with

a score of 10.01. The top three countries/regions rank in the same order on the three indicators, while Chinese Mainland’s placements vary according to the different measures.

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

Indicators	Score						Rank					
	USA	Germany	UK	Italy	France	Chinese Mainland	USA	Germany	UK	Italy	France	Chinese Mainland
RLI_{Cik}	21.96	18.98	15.54	12.94	12.19	10.01	1	2	3	4	5	8
$RFOI_{Cik}$	12.09	9.85	7.99	6.68	5.88	5.59	1	2	3	4	6	7
$RFII_{Cik}$	9.87	9.12	7.55	6.26	6.31	4.43	1	2	3	5	4	8



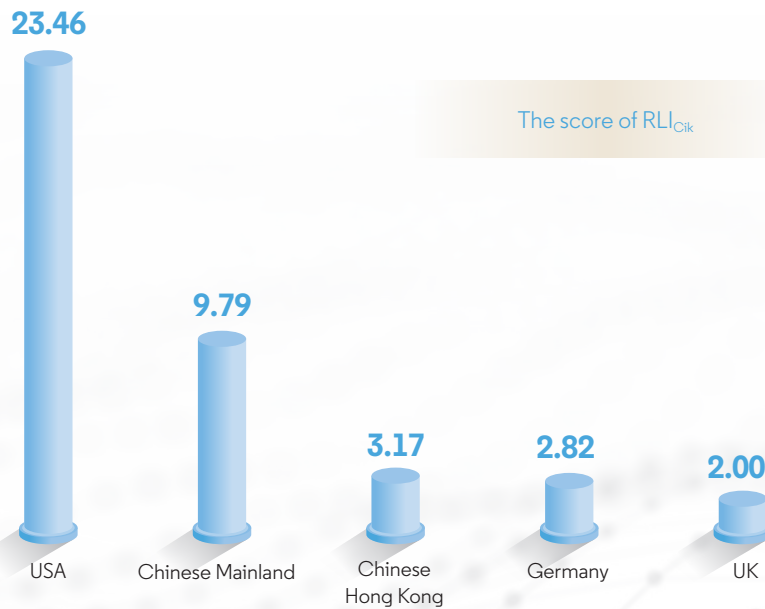
3.9 MATHEMATICS: The USA is the most active; Chinese Mainland is 2nd; Chinese Hong Kong, Germany, and the UK are 3rd to 5th

In the area of “Mathematics”, the USA achieves the most active performance and ranks 1st, with a score of 23.46. Meanwhile, Chinese Mainland posts a score of 9.79, ranking 2nd. but there is still a significant gap compared to the USA. Chinese Hong Kong scores 3.17, ranking 3rd. Germany and the UK score 2.82

and 2.00, respectively, ranking 4th and 5th. The rankings of the top four countries/regions according to the three indicators are completely consistent, while the rankings of the UK vary slightly among the three indicators.

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

Indicators	Score					Rank				
	USA	Chinese Mainland	Chinese Hong Kong	Germany	UK	USA	Chinese Mainland	Chinese Hong Kong	Germany	UK
RLI_{Cik}	23.46	9.79	3.17	2.82	2.00	1	2	3	4	5
$RFOI_{Cik}$	12.21	6.04	1.63	1.38	1.09	1	2	3	4	6
$RFII_{Cik}$	11.25	3.75	1.54	1.44	0.91	1	2	3	4	5



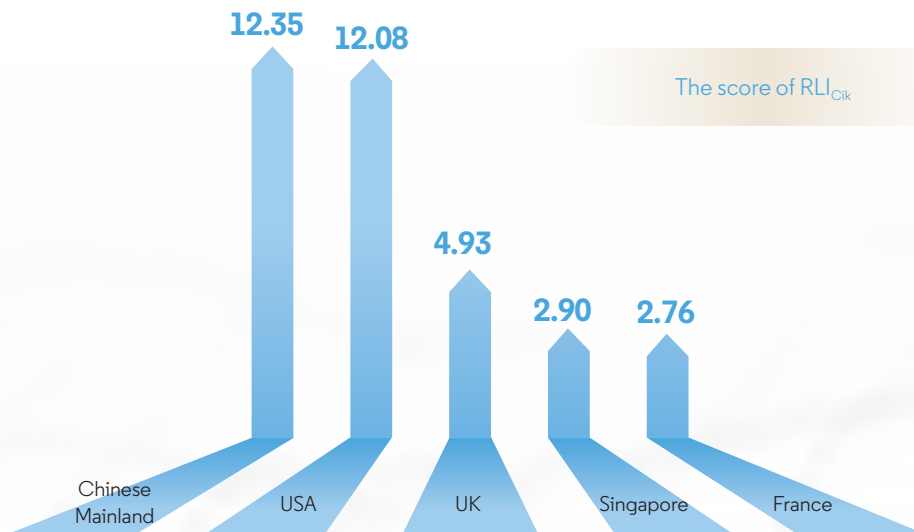
3.10 INFORMATION SCIENCE: Chinese Mainland and the USA are the most active; the UK, and Singapore, and France rank 3rd to 5th

In this area of “Information science”, Chinese Mainland and the USA are the most active, with respective RLI_{Cik} scores of 12.35 and 12.08. The UK scores 4.93, ranking 3rd. Singapore and France score 2.90 and 2.76, ranking 4th to 5th, respectively.

The rankings based on the three indicators for the UK maintain the same rank. The placements of Chinese Mainland, the USA, Singapore, and France vary slightly according to the three indicators.

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

Indicators	Score					Rank				
	Chinese Mainland	USA	UK	Singapore	France	Chinese Mainland	USA	UK	Singapore	France
RLI_{Cik}	12.35	12.08	4.93	2.90	2.76	1	2	3	4	5
$RFOI_{Cik}$	7.48	5.60	2.57	1.49	1.18	1	2	3	4	6
$RFII_{Cik}$	4.86	6.48	2.36	1.41	1.57	2	1	3	6	5



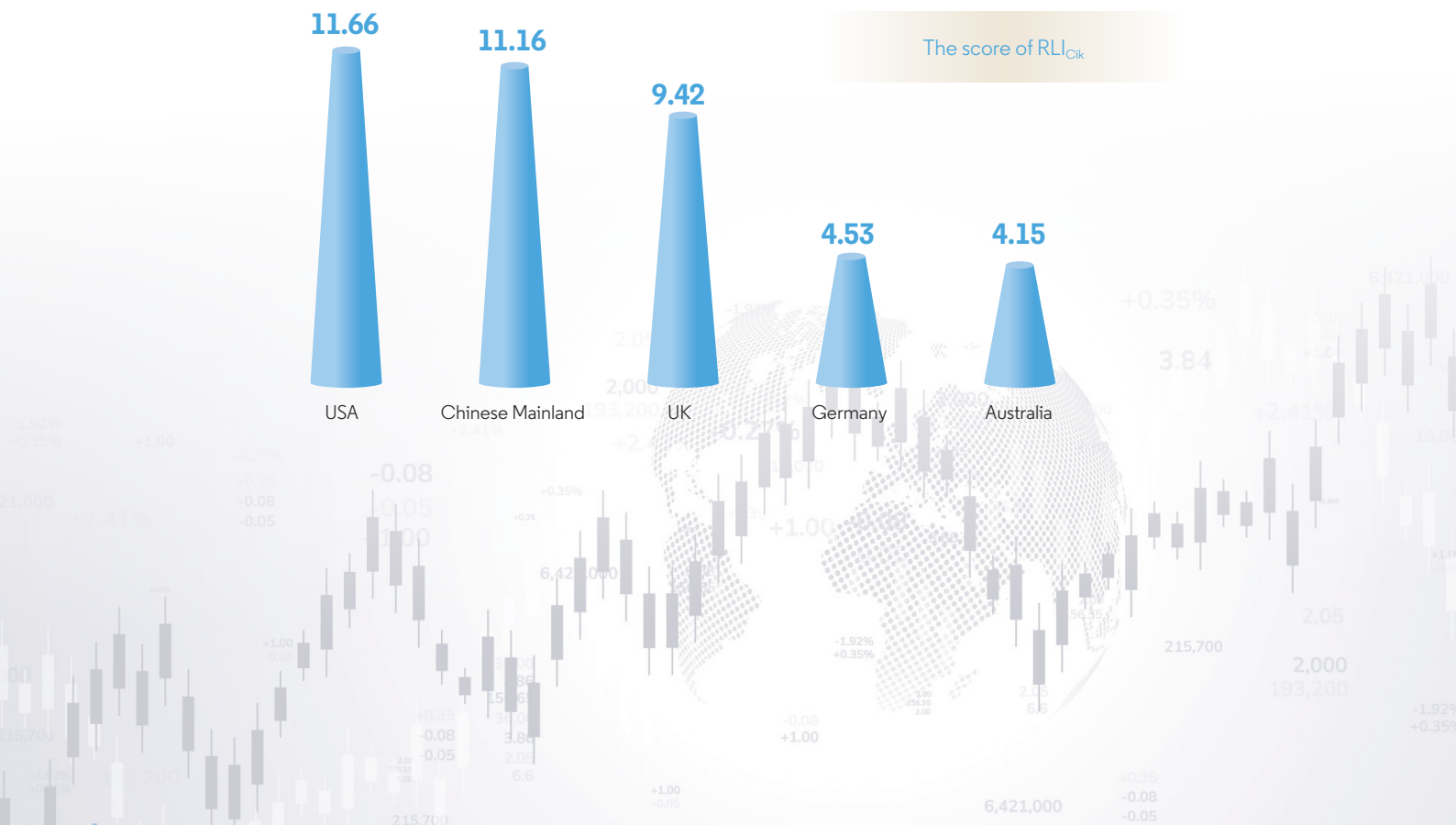
3.11 ECONOMICS, PSYCHOLOGY AND OTHER SOCIAL SCIENCES: The scores of the USA and Chinese Mainland are close; the UK, Germany, and Australia rank 3rd to 5th

In this area of “Economics, psychology and other social sciences”, the RLI_{Cik} scores of the USA and Chinese Mainland are very close, at 11.66 and 11.16, respectively. The UK scores 9.42, ranking 3rd. Germany and Australia rank 4th and 5th with

4.53 and 4.15, respectively. For the Top five countries/regions, the rankings based on the indicators RLI_{Cik}, RFOI_{Cik}, and RFII_{Cik} are the same across the board.

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

Indicators	Score					Rank				
	USA	Chinese Mainland	UK	Germany	Australia	USA	Chinese Mainland	UK	Germany	Australia
RLI _{Cik}	11.66	11.16	9.42	4.53	4.15	1	2	3	4	5
RFOI _{Cik}	6.19	6.15	4.94	2.16	1.90	1	2	3	4	5
RFII _{Cik}	5.47	5.01	4.48	2.37	2.25	1	2	3	4	5



2023 Research Fronts:
Active Fields, Leading Countries/Regions



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