Growing strength

A number of countries are having a clear impact on the expansion of high-quality materials-science research. By Esme Hedley

Materials science is a field that is seeing strong growth in the Nature Index. From 2019 to 2023, there was a 25% increase in the number of articles in the database related to the subject and last year these papers represented 27.2% of all research in its journals. In terms of the countries publishing this research, China now represents around half of global output. But other Asian nations, and some outside the region too, are making significant contributions. Here, we focus on five countries whose materials-science output over the period is noticeable for variety of reasons. South Korea has consistently maintained a top-five position by growing its Share, India is a rapidly emerging force in the field, Singapore stands out as a key location despite its size, and two European nations — Italy and Denmark — seem to be bucking the trend for Western countries losing Share.

South Korea

Population (2023): 51.71 million
GDP per capita (2022): US$32,395
Researchers (full-time equivalent) per million inhabitants (2021): 9,081.9
Nature Index materials science rank: 5

South Korea is an important player in materials science and has ranked fifth by Share in the field every year from 2019 to 2023. The field is a clear priority for the country, as reflected by its proportion of materials-science Share relative to its overall Nature Index output (49.7%), a figure that is higher than China (45.7%) and more than three times higher than that of the United States (15.4%).

The quality of its materials-science output is shown by South Korea-based researchers authoring the most highly cited Nature Index paper in the field in 2023. The scientists, mainly from the Ulsan National Institute of Science and Technology, developed a perovskite solar cell with a certified power-conversion efficiency of 25.7%. The article[1], which was published in *Nature*, had been cited 972 times at the time of Nature Index's data analysis.

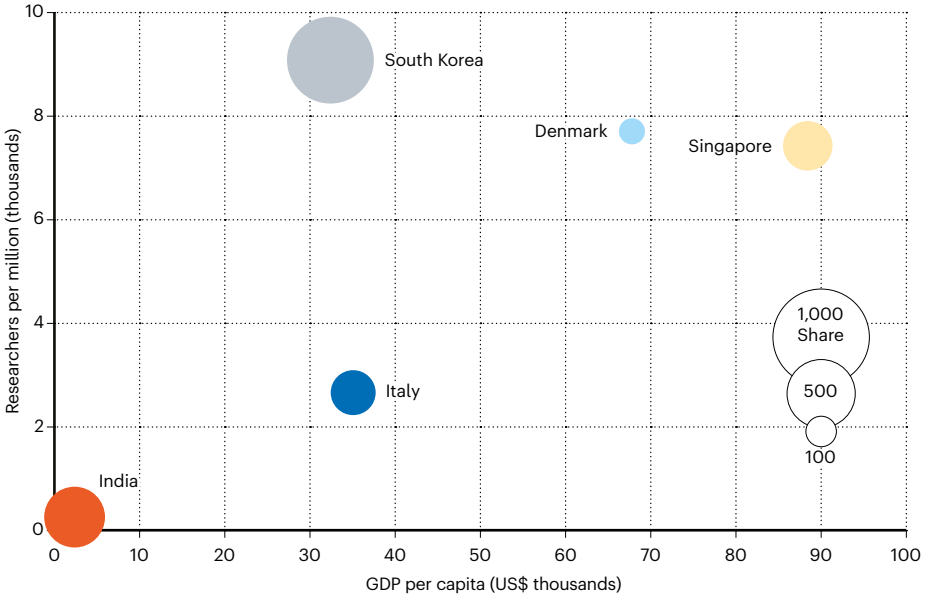
The country is a big spender on research and development (R&D) and has world-leading numbers of researchers relative to its

SOURCE: NATURE INDEX/UNESCO/WORLD BANK

SOURCE: NATURE INDEX

WEALTH CREATION

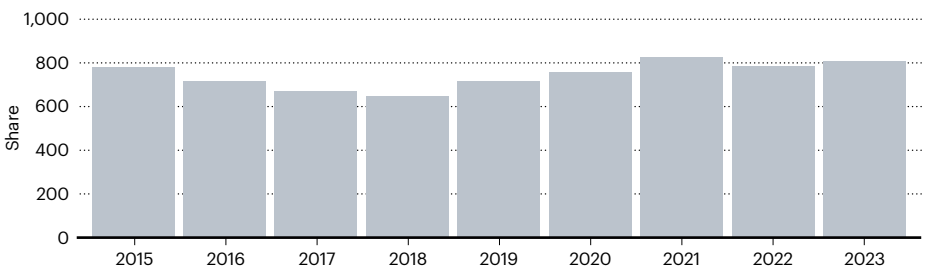
These five countries are relatively strong contributors in materials science, despite having different population sizes, overall wealth and researcher numbers. India has the potential for huge growth if it can grow its pool of scientists, while South Korea's output arguably shows the benefit of investing heavily in science despite having a slightly lower GDP per capita.



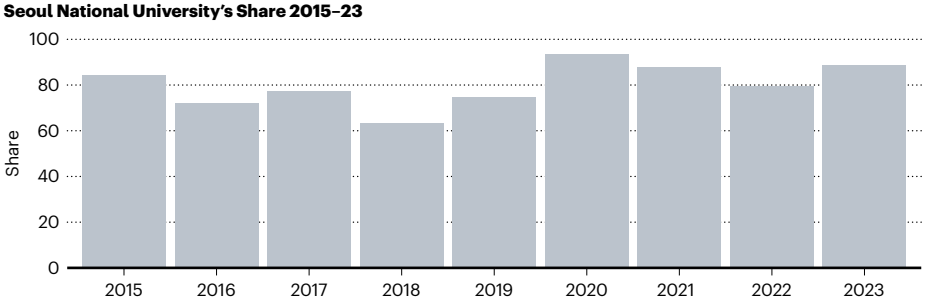
ON THE UP

South Korea was the third-highest rising country in materials-science output from 2019 to 2023, with a 13% increase in its Share, a turnaround from a dip in Share from 2015 to 2018. This national trajectory was mirrored in the output of its leading institution in the field, Seoul National University.

South Korea's Share 2015–23



Seoul National University's Share 2015–23

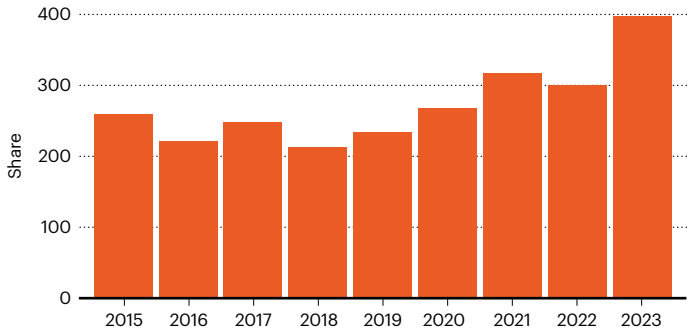


index

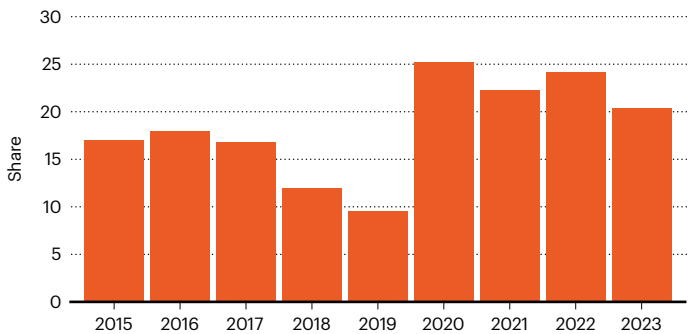
CONSISTENT GAINS

Although its Share in materials science is still way behind China's, India's output in the field in the past few years has been going in the right direction, almost reaching 400 in 2023, a 70% gain compared with 2019. Its leading institution in 2023 was the Jawaharlal Nehru Centre of Advanced Scientific Research, in Bengaluru.

India's Share 2015–23



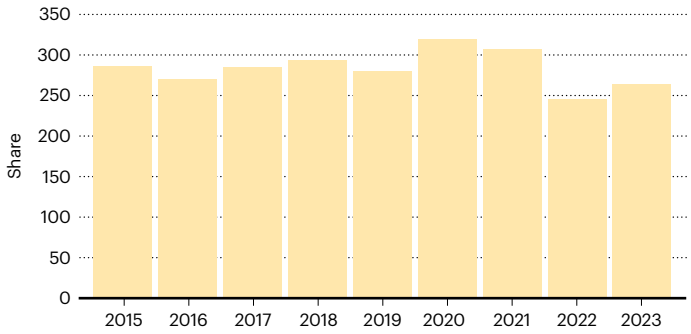
Jawaharlal Nehru Centre for Advanced Scientific Research's Share 2015–23



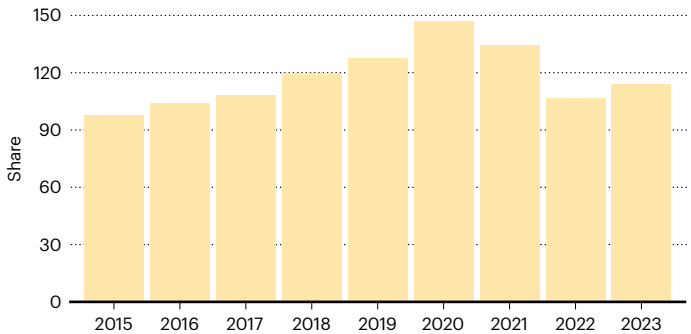
SOLID STATE

The city state of Singapore is the 10th leading country or territory for materials science in the Nature Index, despite only having a population of around six million people. Its leading institution in 2023, the National University of Singapore, is firmly in the world's top 50.

Singapore's Share 2015–23



National University of Singapore's Share 2015–23



SOURCE: NATURE INDEX

population size, according to statistics from the United Nations cultural organization UNESCO. But with a birthrate that is also the lowest in the world and dwindling numbers of students going into higher education, South Korea has challenges to overcome to remain as a global leader in science.

India

Population (2023): 1.43 billion
GDP per capita (2022): US$2,366
Researchers (full-time equivalent) per million inhabitants (2020): 260.4
Nature Index materials science rank: 7

India's ranking in materials science in the Nature Index has been steadily rising, climbing six places from 2019 to 2023 with its Share rising by 70% across this time period, from 234.11 in 2019 to 397.64 in 2023. Between 2022 and 2023, India's percentage increase in Share was 33%, higher than China's (22%), although these figures represent increases in Share of 97.85 for India and 1,879.29 for China.

India also has the lowest article Count among the ten leading countries in materials science. This indicates that scientists from India are, on average, collaborating less with researchers in other countries on materials-science papers tracked by the Nature Index, which could be an area to improve in the coming years. India did not feature in any of the ten leading country pairs in materials science by bilateral collaboration score (CS), in contrast to China which features in seven of these.

Given its large population and commitment to materials science as a priority area (its materials-science Share relative to overall Share is 26.6%), India has huge potential to further climb the rankings. But it might need to ensure it invests in retaining domestic talent before it moves to other countries. Although the Indian government has attracted science and technology students using large numbers of scholarships and fellowships, the country's research expenditure (from government and non-government sources) as a percentage of GDP (0.64% in 2020–21) is much lower than major research systems such as China (2.56% in 2022) and the United States (3.59% in 2022). One way to boost this figure will be increased private investment, which at around 40% of total research spending is a relatively low proportion by international standards.

Singapore

Population (2023): 5.92 million
GDP per capita (2022): US$88,429
Researchers (full-time equivalent) per million inhabitants (2021): 7,425.8
Nature Index materials science rank: 10

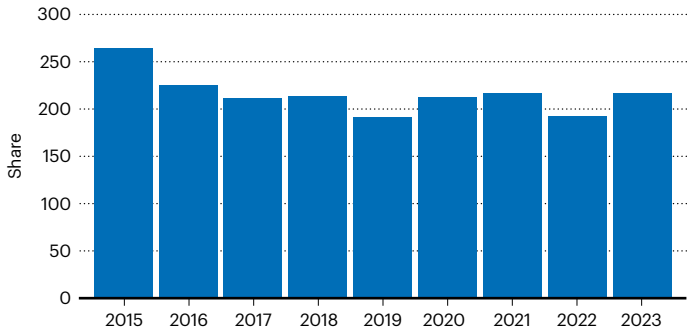
Singapore is a country that has a very high concentration on materials science: among the leading 20 nations, it has the second-highest percentage for materials-science output as a proportion of overall output in Nature Index journals (48.6%). Although the city state is the smallest country in southeast Asia by surface area, its research collaboration with China in the subject is the second strongest in the world with a bilateral collaboration score (CS) of 400.2; effectively meaning the partnership produced 400 Nature Index papers together. Singapore's contribution to this collaboration was also far from small: it represented around a third of the CS produced by the pair. The leading international institutional partnership in materials science involving Singapore in 2023 was between the National University of Singapore (NUS) and Tianjin University, China, with a CS of 43.04. The NUS was also the third highest non-Chinese academic institution for materials science in the world by Share, after the Massachusetts Institute of Technology and University of Tokyo

The importance of the Singapore–China collaboration might reflect the city state's

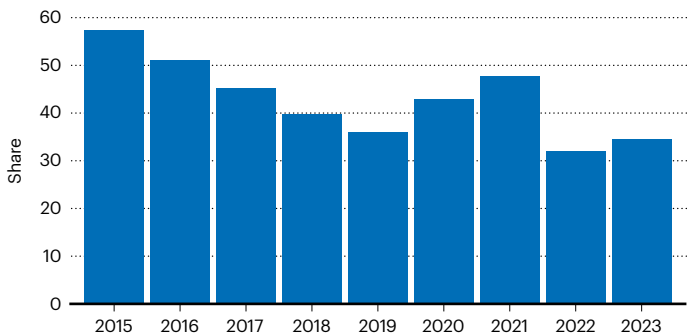
HOLDING PATTERN

Italy experienced a noticeable fall back in its materials-science output from 2015 to 2016, but it has since maintained a steady contribution that breaks the Share barrier of 200 in most years. Its leading 2023 institution, the National Research Council, has had more varied output.

Italy's Share 2015–23



National Research Council's Share 2015–23

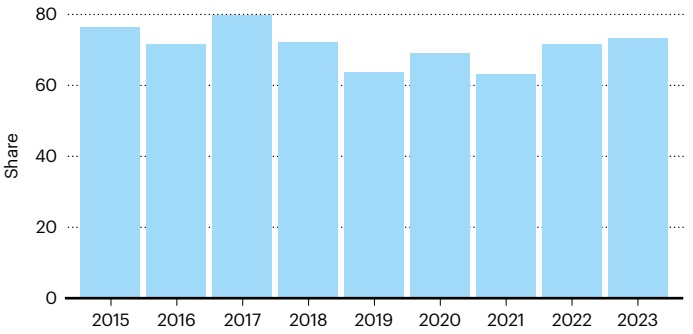


SOURCE: NATURE INDEX

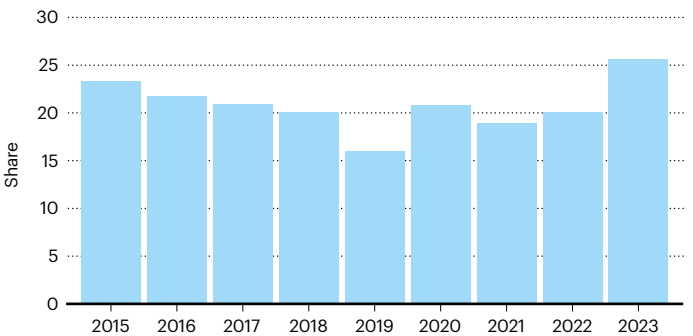
GREEN SHOOTS

Denmark's Share in materials science in 2023 was less than one-third of Singapore's, despite the countries having similar population sizes. But there are signs that the European nation is boosting its materials output, as shown by the recent performance of its leading institution in 2023, the University of Copenhagen.

Denmark's Share 2015–23



University of Copenhagen's Share 2015–23



ongoing engagement with China's global infrastructure development strategy, the Belt and Road Initiative (BRI). A previous analysis by Nature Index showed Singapore as China's strongest BRI partner. But country-specific trends in how researchers are identifying themselves on papers might mean high international collaboration scores between China and countries such as Singapore might in part be made up by Chinese researchers working with Chinese researchers.

Italy

Population (2023): 58.76 million
GDP per capita (2022): US$35,069
Researchers (full-time equivalent) per million inhabitants (2021): 2,677.8
Nature Index materials science rank: 14

Italy performs consistently in the rankings for materials science, placing 14th in the past three years, an improvement on one place from 2019 and 2020. Its Share of 217.13 was lower than Singapore (263.89) and South Korea (810.22) but it was the top-ranked European country for change in Share from 2019 to 2023, with a 13.5% increase across the period

Its relatively strong performance in the field might reflect a prioritization of physical science more generally: it was ranked eighth globally for the subject with a Share of 634.19 in the Nature Index 2024 Research Leaders tables, ahead of Switzerland, India and Canada. Across all subjects, however, Italy ranks 11th in the world – below these three countries – with a Share of 1313.44.

According to data from a 2021 survey funded by the European Commission – the Mobility Patterns and Career Paths of EU Researchers – researchers and PhD students from Italy move between countries significantly more than the European Union average, to seek better working conditions and pay, and advance their careers abroad. Talent retention, therefore, is something Italy might need to consider if it is looking to become one of the leading countries in materials science.

Denmark

Population (2023): 5.95 million
GDP per capita (2022): US$67,790
Researchers (full-time equivalent) per million inhabitants (2021): 7,707.7
Nature Index materials science rank: 22

Denmark has seen a steady increase in its Share in materials science across the five years of Nature Index's latest analysis (2019 to 2023) with a rise of 15% across the period. But in terms of ranking, it dropped two places from 2022 to 2023 and might need to do more to break into the leading 20 countries given its relatively small output. There are also much bigger countries seeing large increases in Share: across the same period India saw its output increase by 70%, whereas China's went up 85%.

There is evidence that Denmark punches above its weight in the field, however: normalizing its Share for population gives it a higher figure per million people than the United States, United Kingdom or Germany. Denmark is a country keen to be a leader of the green transition and new technologies associated with this, often using its natural strengths such as connections to sea-related industries. In 2023, researchers from Aarhus University showed that chemical recycling approaches for thermoset epoxy resins and composites were achievable[2]. These materials are found in the shells of wind-turbine blades and this new approach could lead to a reduction in the number of wind-turbine blades sent to landfill.

Esme Hedley is a science writer based in London.

1. Park, J. *et al. Nature* **616**, 724–730 (2023).
2. Ahrens, A. *et al. Nature* **617**, 730–737 (2023).