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THE CHALLENGES FACING RESEARCH COLLABORATIONS

The pandemic and political tensions might slow the march towards more globalized science. **By Brendan Maher and Richard Van Noorden**

In February 2020, as early COVID outbreaks were expanding in many countries, Nevan Krogan was grappling with a different kind of surge – in the size of his research collaboration. Krogan, a systems biologist, had been focused on tackling pressing issues in biology and health by forming interdisciplinary collaborations

through the Quantitative Bioscience Institute (QBI) at the University of California, San Francisco. His colleagues were eager to work on the new coronavirus – and they soon had lots of company.

What started as 10 scientists around a table jumped to 12 groups within a week, then to 42. When lockdowns started in March, the team's

first Zoom call was exhilarating but chaotic. Hundreds of people joined, says Jacqueline Fabius, the QBI's chief operating officer.

Even though the institute specializes in bringing people together, the way everyone clicked into gear to work on COVID-19 was a surprise. "Different disciplines fit together much more seamlessly than I would have

expected,” says Krogan, who directs the QBI.

Within a few months, the collaboration had published research papers that map out protein interactions and other features of the SARS-CoV-2 virus that have helped to identify drug candidates now being tested against it.

Those involved, including funders and industry partners, worked so openly and collegially, says Krogan, that he now wonders whether the rapid progress made on COVID-19 could be replicated for other diseases. “We should ask ourselves why it had to take such a gigantic human tragedy for us to work together,” he and Fabius wrote in a commentary¹ about the experience.

The pandemic could leave its mark on research collaborations for years to come. Many scientists, like Krogan, strengthened existing connections and forged new ones. But the pandemic also interrupted projects and curtailed travel. And it might have intensified the challenges to international cooperation arising from long-standing political tensions, particularly between the United States and China. Analysis by *Nature* suggests that the growth in research collaborations involving the two countries might have started to slow before the pandemic.

There is also growing concern, heightened during the pandemic, about making collaborations equitable for – and beneficial to – all partners. That is still lacking, says Trudie Lang, a clinical-research scientist specializing in global health at the University of Oxford, UK. “The drivers and the rewards for team science just really aren’t there, yet.”

The rise of global collaboration

In the 1990s, the US Office of Science and Technology Policy – an agency that advises Congress on scientific matters – asked Caroline Wagner, then an analyst at the non-profit RAND Corporation, to help it understand the drivers of international collaboration. When she surveyed US scientists, Wagner found that about one-third of those who were collaborating internationally were originally from another country, and were connecting with colleagues there. Another third were collaborating with someone who had worked in one capacity or another in the United States. Scientists were maintaining connections that had been fostered locally, a trend that continues today. “As many as 90% of these international collaborations begin somehow face-to-face or side-by-side,” says Wagner, now a science-policy specialist at the Ohio State University in Columbus. And they do it because it helps the research.

The story of rising international collaboration, aided over decades by cheaper travel and better digital connectivity, is now familiar. Scientists can map this rise by looking at a proxy measure: co-authorship of research papers (see ‘Collaborations on the rise’). In addition

to the steady growth of international collaborations, one other trend has been clear for years: the papers that they produce tend to be cited more than domestically authored papers – a rough but useful measure of their relative impact on a field.

A 2020 study², for example, showed that citation rates increase steadily with each additional country represented in an author list. The boost in impact is unsurprising, says Jonathan Adams, chief scientist at the analytics firm Clarivate in London, and an author of the work. “People certainly don’t get involved in it unless there’s a very good reason for doing so.” Researchers have debated the connection between collaboration and quality, however. One study³ that examined subjective researcher assessments of biomedical papers suggested that, at least for a subset of the literature, international collaboration doesn’t correlate with better quality.

One of the factors pushing the number of collaborations skywards is the rise of China as a research superpower. Although the majority of its papers are wholly domestically authored, its sheer publishing volume means that it has become the leading international partner for researchers in many other countries.

One trend that researchers have noticed is an increase in collaborations involving three or more nations. These now account for around 30% of international collaborations and 7% of all articles, according to a *Nature* analysis of Dimensions, a database owned by the analytics firm Digital Science in London. (Digital Science is operated by the Holtzbrinck Publishing Group, which also has a majority share in *Nature*’s publisher.) Some see the growth as a positive sign. “Generally, this is good news for those interested in knowledge being more global,” says Jenny Lee, who studies the geopolitics of higher education at the University of Arizona in Tucson.

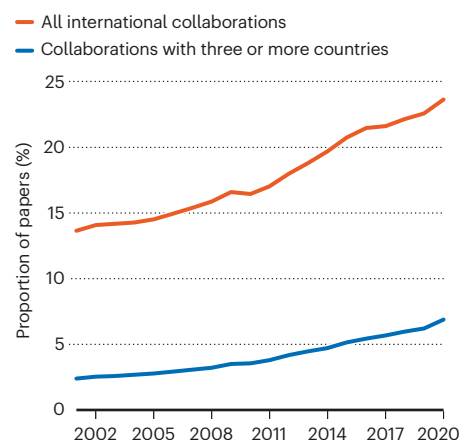
Boom and bust

Early in the COVID-19 pandemic, science leaders talked widely about leveraging global knowledge and working together. Their aspirations were only partly realized. According to multiple analyses of co-authorships of research studies^{4,5}, including *Nature*’s own for this article, the first few months of the pandemic probably did see more international collaboration on COVID-19-related papers than was typical for non-COVID-19 research. But collaboration was less common than for coronavirus research in previous years. As time wore on, the COVID-19 literature saw more domestically authored articles. And in 2020 as a whole, international collaboration rates for COVID-19 research ended up being similar to those for all research, *Nature*’s analysis suggests.

There were some unusual wrinkles in collaboration patterns. In a preprint⁴, Ying

COLLABORATIONS ON THE RISE

The past few decades have seen a rapid rise in the fraction of papers with authors from more than one country.



Ding, an information scientist at the University of Texas, Austin, and her collaborators tracked a decline in international collaboration relative to previous coronavirus research, but also noted a 3% increase in collaborations involving individuals who had never worked together before. These “parachuting” collaborations, as the researchers called them, sometimes involved scientists from different disciplines, and showed signs of greater novelty, as measured by new combinations of biomedical terms; the same signal of high novelty showed up in the international collaborations. The pandemic, Ding says, might have given birth to some creative partnerships (see also ‘Finding that dream-team dynamic’). “Suddenly, everything’s paused, and you have to step out of your comfort zone and start thinking now about the common problem we all face.”

Wagner and her colleagues looked at COVID-19 papers published up to the beginning of last October⁵. They found that coronavirus research teams shrank over this period, and involved fewer nations than was the case before the pandemic. But the teams that were international tended to involve more countries, particularly as the pandemic wore on, a trend that Wagner attributes to the need for diverse expertise.

Researchers have paid particular attention to collaboration between the United States and China, the two nations with the biggest scientific output. In the first few months of the pandemic, these two countries collaborated on COVID-19 papers more than any other pair of nations, and at higher rates than they did for non-COVID-19 science, according to *Nature*’s analysis and work⁶ by Lee and John Haupt, an international-education specialist at the University of Arizona. That was in part because so many of the early papers on the pandemic had authors from China.

But as the pandemic wore on, the United States turned instead to collaborating on COVID-19 papers with other countries, such

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as the United Kingdom, *Nature's* analysis and Wagner's work show⁵. This corresponded with a decline in China's relative contribution to the literature, as case rates went down and as the government restricted the flow of information about COVID-19. Ding says she was affected by these restrictions first-hand when she was working with researchers in Chinese universities to study the flow of misinformation about the new coronavirus. "Some of them said, 'Sorry. They cannot work on COVID any more because that has to get approved,'" Ding says.

Krogan, too, says that building alliances with Chinese researchers has been particularly hard. The QBI was establishing connections in China before the pandemic, and things were going smoothly, says Krogan. But working on coronavirus presented extra challenges. "I know for a fact that over the last year it's become harder," he says. "The pandemic kind of triggered something, politically, I guess." The QBI's coronavirus research group currently has no official partners in China.

The data on collaboration during the pandemic are messy in part because of the massive publishing surge – the number of COVID-19 papers and preprints increased from about 5,000 in the first three months of the pandemic to 150,000 or more by the end of 2020. What's more, preprints aren't always included in the analyses, and comparing the massive infusion of coronavirus-related research with studies in other fields, many of which had to be put on hold owing to lockdowns, is difficult. The data also don't typically capture industry collaborations and their impact.

In a few years' time, Adams says, one might be able to look back and see 'blips' in the research record due to work that stopped because people switched to working on coronavirus, reduced their international travel, or shut down their laboratories. Some scientists have been stranded or unable to hire people for key positions because of lockdowns, and the dearth of in-person meetings, symposiums and conferences has delayed networking opportunities that are especially important to junior researchers. Nevertheless, Adams thinks that COVID-19's impact on collaboration as a whole will be minor, particularly when compared with the impact on society more broadly.

But his is one of the more optimistic views. Others see the pandemic as potentially amplifying some of the forces that work against international collaboration.

Geopolitical tensions

The drop in US–China collaborations on COVID-19 research that Wagner documented represents a small proportion of all the research the countries do together. But it might fit in with a broader slowdown in the growth of their collaboration.

Nature's analysis suggests that although the number of papers with both Chinese and

US co-authors is still climbing, the fraction of China's international collaborations that involve US authors has been declining since 2017 – even as the share of papers co-authored with some other nations, such as the United Kingdom and Australia, is rising. Similarly, the fraction of US international collaborations that include China fell for the first time in 2020, after rising for two decades (see 'US–China collaborations').

And in May, analysts with the Nature Index, a database that tracks 82 well-known natural-sciences journals, reported seeing zero growth in US–China papers in these journals in 2020, after increases in previous years. (Nature Index is published by Springer Nature;

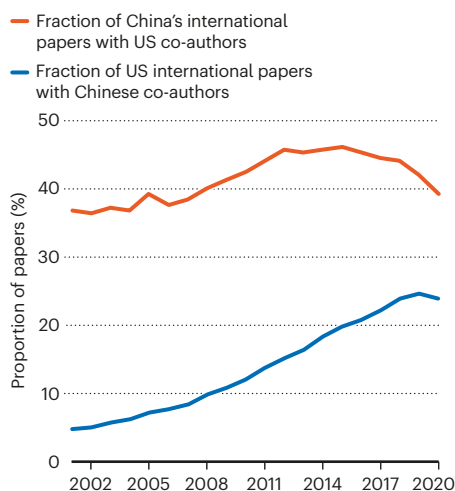
"There's really serious gaps that we would have got over if we'd have had much more collaborative effort."

Nature's news team is editorially independent of its publisher.)

The reasons for the slowdown might relate to government interventions. Fuelled by fears of intellectual-property theft and espionage, the US government has been scrutinizing scientists with ties to China; there have been arrests and sackings for failure to disclose funding from foreign entities and violations of peer review. The punitive measures have had a "chilling effect" on establishing new partnerships, says Cassidy Sugimoto, an information scientist at Georgia Tech in Atlanta. Perhaps more importantly, visa restrictions imposed by the administration of former US president Donald Trump last year might have reduced the number of visiting scholars and students training in the United States. "Any changes

US–CHINA COLLABORATIONS

The number of publications with US-based and China-based authors is rising. But starting in 2016, the fraction of China's international collaborations that include US co-authors began to fall. The share of US collaborations that have co-authors in China dipped more recently.



in policies or regulation around visas affects international collaboration," Sugimoto says. And Chinese scientists already working in the United States might be less inclined to stay: some report feeling less welcome because of rising racial discrimination.

Migration patterns can take a long time to emerge in the data, but limitations were starting to show well before the pandemic. Li Tang, a science- and innovation-policy researcher at Fudan University in Shanghai, points to air-traffic data, for example. Since 2018, these have shown a 10% drop in the number of trips from China to US airports – specifically those near universities that typically host Chinese students⁷.

China's national policies could also be having an impact. In 2020, the government said that Chinese researchers should be evaluated less on the volume of their work in international-journal databases such as the Science Citations Index, and more on the quality of their papers – and that assessments should also consider research in journals published in China. As the number of Chinese-language journals expands, collaborations data could be harder to analyse. The policy could have a profound effect on international collaboration, says Lee.

Established collaborations shouldn't be strongly affected, but new work might be choked, according to researchers. "It'll undoubtedly have an effect when we're not even able to nurture the early seeds in collaboration," says Lee, who aims to explore the appetite for collaboration through interviews and surveys in the United States and China starting later this year.

But some researchers are more optimistic. Even if the rate of growth in US–China partnerships is dropping, the number of collaborative publications is still rising. James Wilsdon, a science-policy researcher at the Research on Research Institute in London, also warns against applying simplistic narratives to China. Despite the powerful levers that its government can pull to influence the way in which science is practised in the country, if researchers in China want to collaborate, they will find ways, he says.

Wilsdon is watching to see how nationalistic political narratives will affect collaboration in other countries. For instance, the United Kingdom's exit from the European Union, which took full effect this year, has raised barriers for some scientists who wish to migrate to the country. And UK cuts to global health-research funding in 2020 were "a destabilizing force", Wilsdon says. Now the UK government is busy smoothing visa requirements for science and technology professionals from overseas; it set up a new Office for Talent last year to attract researchers.

Scientific societies, meanwhile, have been compiling reports in support of international

FINDING THAT DREAM-TEAM DYNAMIC

Scientists who study collaboration are eager to explore how the diversity and structure of teams can influence the quality of research. And that means looking beyond the standard tools for judging research.

Viewing impact only through simple citation counts, for example, isn't ideal, says James Evans, a sociologist and computational scientist at the University of Chicago, Illinois. He and his collaborators are trying to identify patterns that can provide clues to whether that work is new.

One potential indicator lies in how research is cited: "When people cite you, do they cite the things that you cite, or do they just cite you?" asks Evans. The latter, in his models, correlates with research that stakes out new areas for exploration. The former represents research that adds incrementally to previous work. In an analysis of 65 million papers¹, patents and software products, he found that large teams tended to produce research that builds on existing knowledge, whereas small teams' research tended to be more disruptive.

Researchers also peer closely at team structure within papers. Because many journals now require scientists to detail their contributions to a given paper, Evans and other researchers are starting to look at whether team make-ups have a predictable influence on the nature of the work and its

collaboration. The American Academy of Arts & Sciences, for example, in June released its second report⁸ in a series on large-scale international collaborations, detailing the scientific, economic and diplomatic benefits of participating in big international projects such as CERN, Europe's particle-physics laboratory near Geneva, Switzerland.

Open data

Another long-term trend that researchers are watching out for is the push for scientists to share their research data more openly. This was mandated by the biomedical funding charity, Wellcome, for research that it funded on COVID-19, although there have been instances of people circumventing the rules by making data available 'upon request'.

In theory, the push for open data might lessen international collaboration if it is no longer necessary to establish personal relationships to access data. Sugimoto says this could happen, but also wonders whether open data might help to link researchers from across the world by making their work more visible. "It could actually, in some ways, enhance and increase international

impact. The approach can be used to track career transitions from more hands-on 'muscle' roles to conceptual and creative 'brain' roles, Evans says, and it can identify what types of teams produce work that is more innovative, more disruptive or has unusual staying power.

Even factors such as the age of researchers in a group can be tracked, based on the amount of time they have been publishing on a particular topic. In unpublished work, Ying Ding, an information scientist at the University of Texas, Austin, has found that teams with many years of experience — what she calls "team power" — tend to do well, in terms of citations, when there is not much difference in seniority among authors. Papers by lower-power teams do better when there is more of a hierarchy, she says; these teams need some people with more research experience. The worst performers are those with high power and lots of hierarchy, Ding says.

This is a universal pattern in science, she adds, "being proved by millions and millions of teams". She and her collaborators are now looking at how team power is distributed in international collaborations. If a team has ten authors — five from the United States, three from China, two from Singapore — they can identify leadership not just from the last author on the paper, but also from the concentration of team power. "If the leader is the person from Singapore, then the leader is from the minority country. Are these kinds of teams more effective?" Ding asks.

collaboration rather than diminish it," she says.

The benefits of collaborative research are not always shared equally. And many scientists are looking for ways to better understand this unequal distribution — which ranges from credit on papers to downstream economic benefits. Lang points out that during the pandemic, most major international clinical trials have been led by wealthy nations and involved treatments and vaccines that could be administered in hospital settings. The cost, she has argued, is that it has taken a long time to make much progress on the kinds of testing and antiviral drugs that would benefit people in low- and middle-income countries.

"There's really serious gaps that we would have got over if we'd have had much more collaborative effort. And that doesn't mean just working together as a team but also means sharing what we've learnt between teams," says Lang. Collaborative science, she notes, often follows an agenda that suits the bigger, richer partner. It could help to spur better, more independent research in low- and middle-income countries, but it's not there yet, she says.

Science is still driven by rewards that are often given to individuals. "Academics have

it beaten into us to be very competitive," says Lang, and that comes at a cost to team science, she says.

At the individual level, women face particular challenges as members of collaborations. Lesley Thompson, vice-president of academic and government relations at the science publisher Elsevier, says that the company's 2020 analysis⁹ of gender representation in science publications found that women typically have smaller networks of international collaborators than men do.

Several papers have documented how the pandemic probably exacerbated disparities that already existed between male and female researchers. Sugimoto, for example, showed how women's names were falling out of primary authorship roles in preprints, and appearing deeper in the list of authors (see go.nature.com/2xhxqxr). They were also appearing less frequently in databases where scientists register studies, such as ClinicalTrials.gov, suggesting that they were less involved in initiating work. One contributing factor, according to surveys of thousands of female scientists, is that they are being asked to shoulder a great deal more of the childcare duties as a result of school and daycare closures during the pandemic¹⁰.

Leaders of the QBI coronavirus research group have considered these disparities. Fabius says that group organizers demanded equal representation for women at its symposium last June, for example, and it has made philanthropic funds available to the project's female scientists to use for childcare costs or to hire extra help in the lab. "Investing money in that area is incredibly wise," she says. "The infrastructure of the whole system needs to be more flexible with these issues."

Krogan agrees. The pandemic exposed a lot of good things about how people work together, but also a lot of deficiencies, he says. "The onus is on us, as the dust settles, to fix these things."

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1. Fabius, J. M. & Krogan, N. J. *Cell* **184**, 2271–2275 (2021).
2. Potter, R. W. K., Szomszor, M. & Adams, J. J. *Informetr.* **14**, 101075 (2020).
3. Bornmann, L. *J. Assoc. Inf. Sci. Technol.* **68**, 1036–1047 (2017).
4. Liu, M. et al. Preprint at <https://arxiv.org/abs/2009.12500> (2021).
5. Cai, X., Fry, C. V. & Wagner, C. S. *Scientometr.* **126**, 3683–3692 (2021).
6. Lee, J. J. & Haupt, J. P. *J. High. Educ.* **92**, 303–329 (2021).
7. Wang, Z., Tang, L., Cao, C. & Zhou, Z. Available at <https://doi.org/10.2139/ssrn.3739306> (2020).
8. Challenges for International Scientific Partnerships Initiative. *Bold Ambition: International Large-Scale Science* (American Academy of Arts & Sciences, 2020). Available at <http://go.nature.com/3gdahja>.
9. *Gender in the Global Research Landscape* (Elsevier, 2020).
10. Myers, K. R. et al. *Nature Hum. Behav.* **4**, 880–883 (2020).
11. Wu, L., Wang, D. & Evans, J. A. *Nature* **566**, 378–382 (2019).