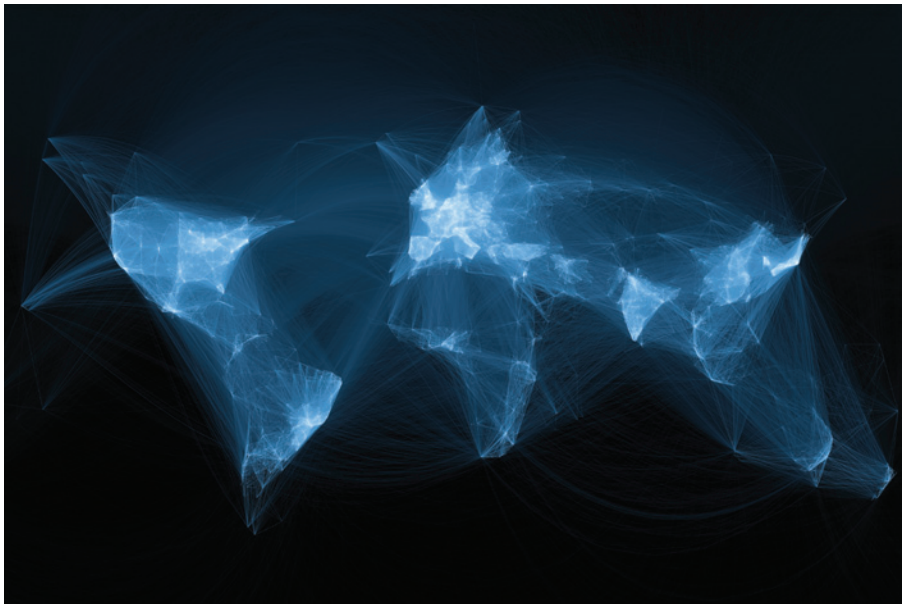

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Bright lines in this map of scientific collaborations between 2005 and 2009 show many joint publications.

The rise of research networks

New collaboration patterns are changing the global balance of science. Established superpowers need to keep up or be left behind, says **Jonathan Adams**.

A fundamental shift is taking place in the geography of science. Networks of research collaboration are expanding in every region of the globe. The established science superpowers of the United States and Europe have dominated the research world since 1945. Yet this Atlantic axis is unlikely to be the main focus of research by 2045, or perhaps even by 2020.

New regional networks are reinforcing the competence and capacity of emerging research economies, and changing the global balance of research activity. This may well reveal different ways of approaching challenges, and solutions that are different to those of Western institutions. If the science superpowers are to avoid being left behind, they will need to step out of their comfort zones to keep up with the dynamism of the new players in this shifting landscape.

Collaboration is normally a good thing from a wider public perspective. Knowledge is better transferred and combined by collaboration, and co-authored papers tend to be cited more frequently[1]. But could increased global collaboration mean a blending of objectives that risks leaving bland priorities?

Co-authorship is a valid proxy for collaboration because few scientists surrender credit for their papers lightly, so we can assume that sharing of authorship reflects a tangible engagement. Such publication data are readily available, cover many countries and research disciplines to a good depth, and have reasonable consistency across decades.

Changes in the balance of research done by the lone scientist and that done by teams can be seen in co-authorship data[2]. Co-authorship has been increasing inexorably[3,4]. Recently it has exploded.

An issue of *Nature* today has a similar number of Letters to one from 60 years ago, but at least four times more authors[5]. Similar observations have been documented from clinical science to law. In the early 1980s, papers with more than 100 authors were rare. By 1990, the annual tally with that number exceeded 500 — and it has kept growing. The first paper with 1,000 authors was published in 2004; a paper with 3,000 authors came in 2008. By last year, a total of 120 physics papers had more than 1,000 authors and 44 had more than 3,000 (ref. 6). Many of these are from collaborations at the Large Hadron Collider at CERN, Europe's particle-physics lab near Geneva, Switzerland.

This upwards trend in multi-authorship will continue through shared global priorities in health, energy, climate and social structures, propelled in part by international agencies such as the World Health Organization. Some of this growth will not be true collaboration but will come from independent contributions to joint efforts, usually in the form of data, that involve only weak intellectual interaction.

THE NEW MAP OF SCIENCE
The changing global landscape of research. nature.com/global

BLURRED BORDERS

Papers with hundreds of co-authors contribute to the apparent pervasiveness of collaboration between countries. For example, every country in Europe co-authors with every other country in the region. For the United Kingdom and Germany, this collaboration is relatively intense and represents many individual links. In 2011, the two countries had around 10,000 joint publications in journals indexed on Thomson Reuters' Web of Science — double the total in 2003 and about 10% of each country's total output. Malta, by contrast, shares only 50 papers per year with the United Kingdom, but that represents more than 25% of its total publication output. Consequently, distinguishing Malta's own science performance is already impossible. This blurring of national distinctiveness could be a growing issue.

According to data from Web of Science, the United States currently collaborates on 3–4% of its papers with each of China (now its most frequent partner, with 19,141 papers in 2011), the United Kingdom (19,090) and Germany (16,753). These totals have all roughly doubled in the past decade and have increased by half as a percentage of US total output. No country shared more than 1,000 papers in 1989 with any partner. US collaboration with Asia is rising steeply, as is collaboration between countries in western Europe. There is no reason to suppose that this will not continue.

China's rapid growth since 2000 is leading to closer research collaboration with Japan (up fourfold since 1999), Taiwan (up eightfold), South Korea (up tenfold), Australia (more than tenfold) and with every other research-active country in the Asia-Pacific region.

The rapid growth of each nation's research base and regional links, driven by relatively strong economies investing in innovation, will undoubtedly produce a regional research labour force to be

reckoned with by 2020. Already, cutting-edge technology can be sourced from research developments in South Korea as well as those in Germany.

India has a growing research network with Japan, South Korea and Taiwan, although it is not as frequent a collaborator with China as one might expect[7]. In the Middle East, Egypt and Saudi Arabia have a strong research partnership that is drawing in neighbours including Tunisia and Algeria. The annual tally of joint Egyptian–Saudi Arabian papers has risen tenfold in the past decade and is accelerating. Less than 5% of these papers have a co-author from the United States, the biggest partner outside the region for both countries.

Latin America has an emerging research network focused around Brazil, which — despite language differences — has doubled its collaboration with Argentina, Chile and Mexico in the past five years. By contrast, Africa has three distinct networks: in southern Africa, in French-speaking countries in West Africa and in English-speaking nations in East Africa.

These clusters indicate that proximity is just one of several factors in networks. Nigeria, for example, collaborates not with its neighbours in West Africa but with co-linguists in East Africa. This mirrors a global tendency to use paths of least resistance to partnership, rather than routes that might provide other strategic gains. Such language links have historically benefited the United Kingdom through alliances with Commonwealth countries that speak English and have adopted similar research structures. The United Kingdom cannot rely on this to continue.

This growth of regional collaboration has many implications. It amplifies the development of emergent research economies. Researchers in Asia, for example, do not need recognition from European and US authors if their research is being cited and used by partners within the region. In the short term, students will recognize attractive opportunities closer to home, with fewer alienating cultural challenges than many European campuses have offered.

Singapore, for example, is already reaping the benefits of a 1998 policy change to attract foreign students. Students from China, India and the ten countries in the Association of Southeast Asian Nations (ASEAN) now comprise about 20% of Singapore's university intake — around 11,000 full-time students — with another 20,000 part-time students in other colleges. Students from those countries choose Singapore for its proximity, its lower cost of living compared with Europe and the United States and its generous government scholarships. Job opportunities are excellent: bursary holders sign a bond to work in Singapore for a fixed period after graduation and the government helps them to find a job that fits their skills[8].

All of this means that the significance of Western research economies as preferred partners for research could dwindle. To meet this challenge, these economies need to do much more than just take fees from immigrant postgraduate students.

The United States and the United Kingdom must build new networks by actively exporting students to burgeoning science centres such as China and India. Researchers must stop expecting scientists from the new powerhouses to come to them, and should visit collaborators to experience different approaches — and be ready to learn, not just to teach. Travelling recently in the Pacific basin, I encountered many university leaders trying to increase collaboration with Europe, but finding it difficult to identify responsive contacts, despite having excellent facilities and staff to offer.

"The maverick and the marginal may find a highly collaborative world a difficult place to flourish."

In short, countries in science's old guard must drop their patrician tendencies, open up clear communication channels and join in with new alliances as equal participants before they find themselves the supplicants.

Collaboration between the public and private sectors has become more apparent because of government interest in exploiting research for economic competitiveness. Some data show that industrial investment in research seems to be dropping — perhaps a reaction to the recession, but the trend seems to be long term, at least in the United Kingdom[9]. Governments need to develop an industrial policy that complements science policy. Incentives for collaborative innovation investment that draws directly on the science base would be a good start.

PATRICIAN TO PARTICIPANT

So what are the costs and benefits of collaboration? It provides access to resources, including funding, facilities and ideas. It will be essential for grand challenges in physics, environment and health to have large, international teams supported by major facilities and rich data, which encourage the rapid spread of knowledge.

Collaborative papers tend to get cited more often. For example, those published jointly by UK and US authors are cited on average more often than either nation domestically. It also works at the institutional level, so Harvard University gets a boost from collaborative papers with the University of Cambridge, and even in *Nature* the US–UK co-papers get relatively more citations[1]. And it follows through to industrial collaboration: when the University of Oxford collaborates with GlaxoSmithKline, for example, the papers are cited roughly four times as often as the world average for their field.

Research networks are a tool of international diplomacy. Germany exports excellent research equipment within its partnerships. China expands its cultural influence through the regional programmes it funds.

As for costs, collaboration takes time and travel and means a shared agenda. Of wider concern as teams proliferate is that individuals could end up working only on topics that peer consensus defines as the most interesting. The diversity of choice and opportunity may be diminished. The risk is that international, national and institutional agendas may become driven by the same bland establishment consensus.

This global tendency for convergence became obvious in 1997 when Tony Blair, then UK prime minister, adopted the same technology priorities set out by Bill Clinton and Al Gore in their 1992 presidential campaign, including biotechnology, health and environment. By 2000, the UK regional development agencies had supported the same missions rather than choose those that played to regional university strengths[10]. Leading research universities in North America, Europe and Asia identify strategic missions in similar areas.

It is difficult to go your own way in a village, even one that is global. But the success of science has been the crossing of separate strands of thought and practice that are more innovative at the edges than at the core. The iconoclastic, the maverick and the marginal may find a highly collaborative world a difficult place to flourish. Research-funding agencies should maintain a balance. Collaborative grand challenges seize headlines, but so do Nobel prizes — and only three people can share one of those. ■

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