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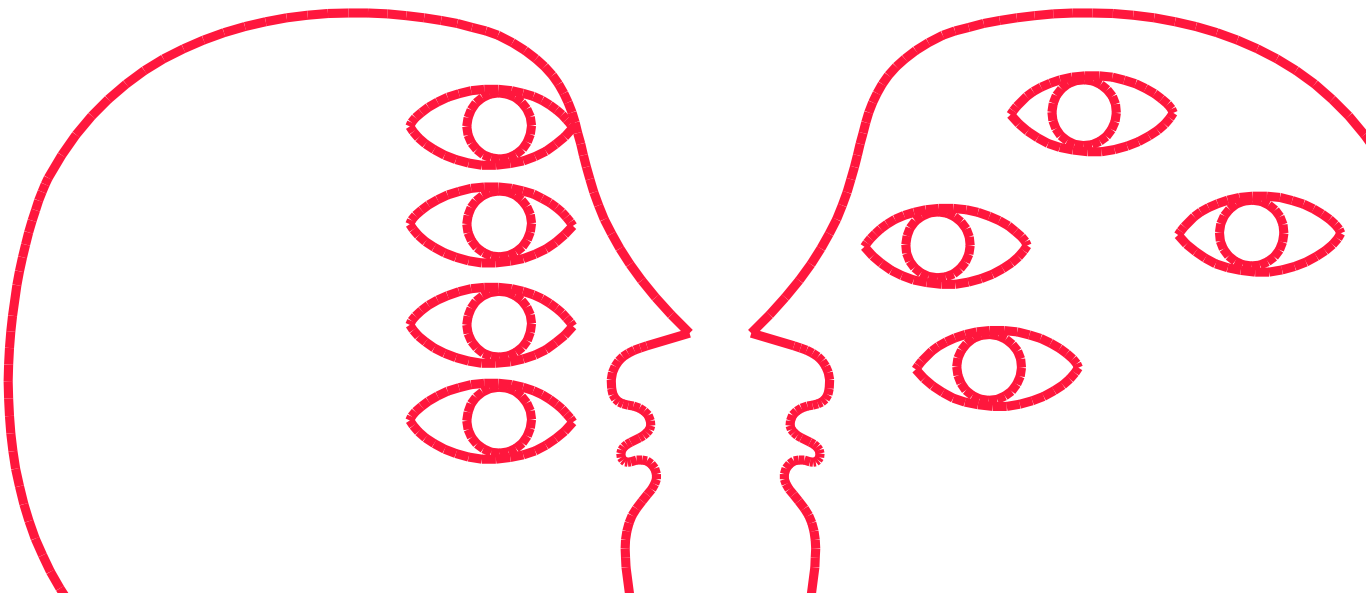
Of Dragons, Turning Tides and Struggling Titans. How to Make Sense of the New World (Dis)order in Science

Summary Report



Foreword

The Robert Bosch Stiftung started the Berlin Debates on Science and Science Policy in 2001. Since then, our ambition with this format has always been threefold. To address mega-trends in science and science policy which affect or challenge scientists all over the world. To find the perfect mix of distinguished guests for each particular subject. And to create a safe intellectual space where ideas can be exchanged openly and solutions formulated.

For this 13th edition, held in Berlin on November 7, 2018, we addressed the most challenging topic we have had in a long time. We talked about the shifts in the global scientific landscape, about new players, about new models of globalized or localized science. This might sound rather innocent. However, it was our intention to not only describe the emerging new landscapes, but also to discuss potential ways of structuring, or maybe even governing this new world order in science. Which ultimately implied: thinking and talking about power. About competition. About who is winning and who is losing, about dominance or fear of being dominated. Because science is no longer (or has never been) an ivory-tower pleasure of noble truth-seekers. It is a multi-billion Dollar business and a powerful driver of innovation and growth. Our challenge as hosts was further intensified by the fact that we held our discussions in a Western city, invited by a dominantly white, Western foundation.

We were perfectly aware of the pitfalls that lie in this constellation – and tried our best to overcome them. First of all, we hosted a group of very diverse experts and decision-makers from all over the world, to make this a truly multipolar debate. And we structured the agenda to lead us away from the zero-sum-logic of the nation state, towards a truly global perspective.

In this global and humanistic perspective, we asked:

- How can we develop and implement globally shared standards for ethics and transparency in science?
- How can we ensure that globalized science continues to prosper, that people and knowledge flow as freely as possible – even in a world full of political turmoil, sanctions or censorship?
- How can we make sure that scientific resources and research results are used for the benefit of humanity and to address the grand challenges, rather than to be seen as tools to advance the economic or political agenda of a single nation state?

On the search for an answer to these questions, at least two directions seemed conceivable: We could rely on the self-organizing mechanisms of the scientific community – a form of market mechanism. Or we could ask for a more centralized, authoritative or participatory form of global governance. Whichever direc-

tion the answers took, we wanted to advance the Robert Bosch Stiftung's overarching aim: to work together on a global ecosystem in which science for all can flourish and grow.

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1. Summary and recommendations

A new global geography of science

After centuries of dominance by Europe and, latterly, the USA, the geography of science is shifting. China, above all, has become - and will remain - a major player. Others aspire to follow the Chinese example. On the African continent, the development might be less spectacular, but nonetheless remarkable, at least in certain countries. The 2018 Berlin Science Debate examined the implications of this shift.

The result will be a scientific world with multiple centers of influence. New voices already shape and will shape scientific agendas and their implementation, and research will be framed by new, perhaps complementary narratives. The questions researchers ask, and the uses to which their results are put, will shift. They will speak to different, more diverse publics, to legitimate their work. How their actual answers will differ remains to be seen.

Much of the discussion explored the extent to which universal standards might be established and/or maintained across the new map of science. Ethical governance of research, and measures to deal with misconduct, need more work to remain attuned to new global circumstances. This also applies for initiatives to maximize access to and exploitation of knowledge for global benefit. In addition, all these efforts need to take more account of historical and cultural differences as new research systems take shape in different countries and regions.

There is also much to consider in relation to the most important research resource: people – and their careers. The USA remains a magnet for researchers from overseas, though recent political changes may begin to weaken the effect. But to what extent should other countries encourage their best researchers to work abroad? What are the benefits, and when might they return? As answers evolve, how best to maintain free movement and the free exchange of ideas, which is the lifeblood of science? Scientists are naturally global citizens, it was said. But what, exactly, might that mean in practice in the 21st century?

Recommendations for a globalized (or cosmopolitanized) science

To maintain ethical standards in global research

- Embed social and ethical issues in science education, at all levels.
- While acknowledging local differences, keep in mind that some standards are (and should be) universal - such as shunning fraud, falsification or fabrication of data.
- Adopt codes of conduct, such as that elaborated by the EC TRUST project, for research partnerships between high and lower-income settings. Build on the general principles of co-production, fairness, respect, care and honesty.
- Align publishers' and funders' policies integrity, research data and other issues.
- Worry less: We are already doing most of what we need to do to deal with scientific misconduct. Scientists' collective interest helps ensure self-regulation can be effective.

To remove borders and barriers and help ensure free flow of people, knowledge and data

- Improve data gathering on movements of researchers, taking account - as far as possible - of the complexity of research careers and collaborations.
- Ensure funders and publishers should collaborate to produce infrastructure and incentives and then mandate sharing of data, materials, protocols and information - genuine open science.
- Ensure acknowledgment, and due recognition, of those who acquire data, as well as the data analysts - through ordering of authorship or other devices.
- Encourage data sharing by researchers by ensuring the papers data sets are linked to or are cited properly by others who may use them, and agreeing user-friendly formats for data input to repositories.
- Make sure that interior ministries understand the importance of, for example, access to visas for scientific conferences, as well as science ministries.
- Remember that indicators are imperfect, and will remain unsatisfactory in some ways even as data collection improves. Simple variables always fall short of capturing the workings of what may best be thought of as a research ecosystem.
- Produce a database of existing charters and protocols on access - building on work such as the Global Open Access Portal. (See http://www.unesco.org/new/en/communication-and-information/portals-and-platforms/goap/). Make it easier for funders to see if they are following best practice.

To ensure that scientific progress is shared globally and used to tackle the world's grand challenges

- Develop co-production. By:

- experimenting with new forms of engagement that allow genuine exchange of values and knowledge.
- appreciating local differences, local culture, local values and local knowledge.
- defining governance structures that draw in new actors, who can help ensure relevance to local constituencies.

- Institute better ways of appreciating/recognizing people who want to do science for public good, across generations.

- Mandate a second abstract for journal papers: a lay summary that explains to a particular community what the benefit of the research is or could be, one day.

- Devise ways for research projects to render sustainability accounting, just as they have to comply with financial accounting.

- Beware mixing research and development in this discussion: they are different things.

- Promote work on grand challenges by changes in funding. Scientists go where the money goes - which is properly a political decision.

- Do not promote top-down initiatives to the detriment of bottom-up funding. Leave room for the best ideas, selected by peer review: trust the researchers.

1. Mapping the New Geography of Science

The rise of China is the most prominent feature of 21st century science trends, by far. A single indicator can stand for many others. In 2003, China's share of the global total of papers in science and engineering was 7 per cent. By 2016, it had grown to 20 per cent.

As Reinhilde Veugelers, Professor of Managerial Economics, Strategy and Innovation, K.U. Leuven, Belgium outlined, other indicators point the same way. Recent shifts in the global share of the top one per cent of papers, of citations, or in the number of science graduates or PhDs, all show China growing rapidly. There are caveats. The nation's rise in biomedical science is less rapid than in other fields, for example. But the overall increase in quantity, and quality, is marked.

The implications of this are still unfolding. The USA remains a magnet for scientific talent. Just over a third of PhDs in science and engineering in the US in 2015 were awarded to non-US citizens. The Berlin Debate coincided with the US mid-term elections, which underlined that there is no hard data yet on any effects that may be evident from the changes there of the last two years. Nevertheless, it appears the flow of PhD students (around 5,000 a year) and postdocs from China to the US is likely to continue. And Chinese scientists and engineers are significantly more likely than those from other countries to extend their time in the US, with four fifths remaining there beyond the end of their doctorate.

The US is also China's most important scientific collaborator, as measured by co-publication. However, the US accounts for a big share of co-authorships in other countries or regions so that is perhaps a reflection of its importance in world science rather than of any special relationship between the US and China.

In Veugelers' view, the overall picture is of a strong US-China nexus, built on "sticky" networks and a sustained flow of people. "Networks of scientific collaboration change very slowly, and are very much correlated with how much mobility there is among scientists", she emphasized.

Multi-polar world: multiple futures

What possible futures follow from a continued strengthening of Chinese research, consolidating a multi-polar scientific world? That depends partly on how China's ambitions play out, she argued. If China emphasizes indigenous scientific capacity, for example, that could imply a reduction in overseas connections, although the increase in the number of researchers would offset that. There is also, of course, uncertainty attaching to the possibility of US retrenchment behind national borders. In the EU, which is less well-connected to Chinese science at present, there may be opportunity for increasing collaboration, but that depends partly on maintaining integration and openness in EU science. And it remains to be seen whether the rest of the world enjoys more opportunities for scientific growth in a multi-polar world, or faces having to deal with dominant regions that are each more inward looking.

Cong Cao, Professor of Innovation Studies, at the University of Nottingham, Ningbo, China put more detail on China's rapid rise - whether measured in terms of spending, number of scientists, papers in international journals, citations, patents, or new China-based multinational companies.

This growth across the board is a result of a committed Chinese effort to reform its domestic science and technology system to make it more effective, efficient and responsive to the challenges of social and economic development. Government policy envisages rejuvenating the nation with science, technology and innovation (hereafter ST&I), expedited by opening up China to foreign ideas, technology and know-how.

Thus far, a top down approach to these reforms has borne fruit, but Cao cautioned that the country has no room for complacency. As Chinese science approaches parity with other nations or regions, individual efforts and bottom-up initiatives may become more important for future progress. And the relatively low spend on basic research - at around a quarter of the Government's support for R&D, accounting for just five per cent of the national total spend - may indicate that a "follower and free-rider" mentality has not yet entirely dissipated.

Where China leads, can others follow?

The speed of China's rise to prominence can make it harder to get a clear view of developments in some other regions. Review global data, and the rapid change in China's contribution to ST&I registers so strongly that it drowns out other signals. Nevertheless, China is only one example of what speakers at the meeting considered a general trend. Governments just about everywhere, it was said, recognize the importance of ST&I for the future. But results elsewhere are less spectacular, so far.

In Africa, not surprisingly the picture is very mixed. As Tade Aina, Director of the Partnership for African Social & Governance Research (PASGR), Nairobi put it, the key thing to bear in mind is that the continent is complex, and scientific effort may be fragmented. Analysis needs to be more nuanced and context-specific. As he reminded the meeting, China is a single country, while Africa has 54 different states. They vary in size, governance, politics, and education systems. For example, there is a strong resource pool in countries such as South Africa, Nigeria, Ethiopia and Kenya. But attention is also needed to issues of governance and politics, infrastructure and systems, and the nature of investment. A country like Rwanda may be low in current resources but is strong in leadership, governance and the creation of an environment for investment in science, technology and innovation.

Moreover, continent-wide database coverage is poor. "There will be no transformation in the continent in relation to ST&I or Higher Education systems if we do not take data very seriously.", he said.

He argued that China's "massively strong state" was a key to the nation's scientific rise. African countries faced a range of circumstances, and it was relatively rare for a single nation to enjoy both strong scientific resources and infrastructure *and* effective state support and governance. In the end, he stressed, growth and transformation of ST&I in any country need political action, which in turn depends on creation of a constituency and coalitions that support science. Leadership in this regard was commonly a weak link, and developing African leaders was crucial: "This must be home grown. No matter what the investments are from outside, the indigenous factor is going to be what is significant in changing the continent."

On the question of mobility of scientific talent within Africa, South Africa used to be the major draw, but some regional hubs are beginning to emerge, as in Nairobi or Dakar. And there is cross-national collaboration in areas where no single nation can offer the capacity needed. Pamela Andanda, Professor of Law at the University of the Witwatersrand, pointed out that some who have come to South Africa from other nations on

the continent remain there because they believe that is where they can best contribute to Africa as a whole.

Science and science policy in Arab countries are also hampered by weak institutions, and reliance on an extractive economy, according to Samia Nour, Professor of Economics at the University of Khartoum. There has been a measurable increase in activity, with a modest increase in the region's share of global R&D expenditure (up from 0.8 per cent of the total in 2007 to 1.00 per cent by 2013), and rises in R&D intensity and in the number of publications. This is mostly state-led. In most Arab states, the majority of R&D is government-funded, with private sector efforts as yet poorly developed. One indication of change to come is that more Arab governments are beginning to monitor their own science systems, with such efforts already under way in Egypt, Jordan, Lebanon, Palestine and Tunisia.

How can we understand scientific development?

In discussion several contributors emphasized that indicators are imperfect. It is not advisable to assess movements in national science and technology only on simple variables, even if this is where we have usable data. Our thinking should embrace the entire research ecosystem, said Helga Nowotny, Chair of the ERA Council Forum in Vienna.

It is also helpful to broaden the discussion to take in other countries, and other histories, urged Jean-Pierre Bourguignon, President of the European Research Council. South Korea is particularly instructive, in his view. Its success in growing its science and technology system rests on steady support for education, a policy that has been kept up for 60 years as governments come and go. The moral of the story here is that deep change takes a long time, but sustained effort can yield extraordinary results.

But such a policy also has to be monitored, lest progress hit a ceiling because some other factor blocks access to the next level in research. In Korea, it became apparent - and was ultimately recognized by governments - that the intensity of basic research needed a separate boost.

This related to earlier comments about China's support for basic research, but Ulrich Schreiterer of the WZB Berlin Social Science Centre wondered if calling for more investment in basic research relied on earlier concepts of research organization, dating back as far as Vannevar Bush's report to the US government on the "endless frontier" in 1945. The overview produced by Nowotny and colleagues in the 1990s, in *The New Production of Knowledge*, outlines new modes of work that involve more complex, and contingent formations than older models of research. This suggested one should be cautious about identifying a lack of basic research in China.

That, and the importance of local cultures, also means that Korean efforts to boost basic research might be compromised. In 2013 South Korea identified what was dubbed a "glass ceiling" in basic research. The response was to try and copy foreign models like the Riken Institute in Japan and Max Planck in Germany. However, argued Schreiterer, "the whole working of the Korean research and science systems are completely out of tune with that. The attitudes, the motivations, the workings of how people do their research and what they are looking for need to be readjusted and tuned and I'm not sure this is going to be as easy as to found a new institution and put a lot of money into it."

Nor is it straightforward to induce researchers who have benefitted from experience abroad to return home, or to allow them to develop their work when they do. Sociologist Joy Zhang, from the University of Kent, distinguished between the flows of knowledge and people, and transfer of other aspects of research culture. It might be that Chinese scientists who train in the US revert to a Chinese way of doing things when they return. She cited a prominent Chinese stem cell scientist who had stayed in the UK because he believed he could contribute more to Chinese science that way. If he had gone back, he feared, the research culture and institutional structure would not have allowed him to do his best work. Ingrid Wünning Tschol of the Robert Bosch Stiftung observed that German researchers had identified early independence as one of the strongest inducements to return to the country after training abroad.

Importing researchers: sign of strength, or weakness?

Another feature of the current landscape that can be read different ways is the continuing movement of researchers from China to the US. North America is still a powerful draw for Chinese researchers, although the balance of movement has changed. Wei Yang, lately President of the National Natural Science Foundation of China reported that 15 years ago the ratio of incoming to outgoing researchers in China was about 1:7. It has now shifted to around 6:7, which Yang held was about right: “We think 1:1 is not the best way”.

The demand for overseas skills suggests that the US cannot furnish the workforce its research system needs, suggested Bourguignon. On the other hand, as Max Voegler, Vice-President, Global Strategic Networks for Elsevier in Berlin, pointed out, US success in enticing researchers from overseas to stay was also a sign of strength - and a potential lesson for other regions. “If you have a system that is good at integrating the people that come to it you can build capacity for high-quality research in the long run”. And at the moment the US is much better at getting people to come, and wanting to remain, than the EU, over both short and medium term. The important factor here, Carlo Rizzuto, Chair of the General Assembly of CERIC-ERIC in Trieste, argued, was that - whatever filters apply on entry - it is easy to enter into US society at every level: “once you’re in, you’re in”.

All of these considerations might be put under the heading of culture, in its broader sense. And that led, finally, to a first airing of the large questions of the role of science in global culture, and how the culture of science relates to other aspects of social organization. Thomas Potthast, Chair for Ethics at the University of Tübingen, observed that applauding the general trend for governments to support science, technology and innovation indicated a shared assumption that more R&D, and more science, makes the world better and improves the human condition: “the old Western, universalist Enlightenment narrative”.

Yet we know that some developments have caused harm, and if that is not acknowledged an important part of the discussion never develops. A simple inspection of research agendas discloses an emphasis on supposed defense needs, and on conquering markets. How does that relate to visions of a just and equitable world, or to the need to respond to climate change? These are not always questions that can be aired. “There are countries where young people can question their professor, but certainly not the government”, said Flavia Schlegel, Assistant Director-General for Natural Sciences at UNESCO).

However, as she summarized, the overall aim is not necessarily just seeking more science and technology across the board. It is for each country to be able to exploit all

their talent, and produce knowledge appropriate to their own culture, history and heritage – and make value for the common good.

2. What does "globalized science" mean?

Science's knowledge claims are global, but scientific work has historically been spread very unevenly across the globe. Spreading intensive practice of science more widely raises a host of questions - not least whether and how globalized science looks different from what came before.

Joy Zhang, pondering broader lessons from the Chinese example, believed there has been a significant change in both the orientation and the governance of science. Globalization is a handy label to reach for here, but she proposed a different process is under way that needs characterizing in more detail. A better term for the emergence of stronger contributions to shaping our scientific future from developing countries would be *cosmopolitanization*.

She saw complementary trends underlying this process. A heightened awareness of scientific uncertainty, and risk, means that research becomes legitimized in more complex ways, and research agendas multiply. With no single right way to develop science, different countries can have different, but equally valid research agendas. Far from globalization, we may see fragmentation in views of emerging science, especially aspects of life sciences such as regulation.

At the same time, whether a national research agenda becomes influential at a global level depends on a negotiation with the interests and concerns of others. This is not straightforward in an arena where historical strengths have been so unevenly spread. Permissive regulation and heavy investment have given China a voice in global science. But China, like other developing countries, "is still struggling to extend the epistemic vision of what science is", said Zhang. If China speaks, who listens?

A telling example comes from recent high-profile life science. China developed the world's first human hybrid embryo in 2001, which was celebrated there as a big step forward. But the international reception was much cooler. "When this result was presented to the world it rapidly became the most controversial piece of research of the year, and won China the famous characterization as the Wild East". China responded with a blanket ban on related research.

However, when the UK picked up the same practice seven years later, it did not attract international condemnation, possibly because the UK's decision was perceived as having gone through a rigorous consultation with stakeholders at home and abroad. The story shows, she suggested, that, "If a country does not actively engage with communicating its research agenda with the global audience, research productivity is not sufficient for any country to challenge a Western model of science."

One implication is that cosmopolitanization is a prescription as well as a description. Chinese regulatory institutions still operate on a model which is narrowly focused on finding a fix for problems raised by international criticism. Individual scientists in China, though, may have a stronger cosmopolitan mindset, exemplified by their pioneering, internationally influential, efforts to frame guidelines for stem cell research, well before their government considered the issue.

Joy Zhang´s conclusion from these episodes is that for the new scientific order to achieve general global benefit calls for both technical and value contributions from different societies. China, as a significant new power in science, needs to get comfortable with the need to engage, “so we can expand the global epistemic vision of what good science is”.

New geography of science: and new research agendas?

This raised queries about what we are taking from that term “epistemic”. As Potthast formulated it, there will be different regional and national styles of science and technology. But what does that mean for the contents of knowledge? “Is there a specific East-Asian knowledge on climate change which is not the same, content-wise, as Western knowledge?” One might ask the same question about African or Arabic knowledge.

Aina was skeptical. “It’s important to ask what kinds of alternatives China is providing the rest of the world, in organization and epistemology. A lot of us look to China and we thought there was hope. Then they tell us they want 50 MITs!”

Tumani Corrah, Director of the Africa Research Excellence Fund, focused on building capability to tackle locally vital research agendas. The objective for Africa should be ensuring science partnerships are balanced and equitable, and there are benefits for all parties. That hasn’t worked that well so far, according to Corrah. Existing partners from the global North, both academic and commercial have ignored capacity building, except when it suited them to develop technical capacity to support their own programs. The result was the scientific equivalent of the extractive agricultural economy. “The whole African research agenda is defined from outside.”

Health research offers some of the starkest examples. List the ten most successful health research centers across the continent outside South Africa and all are funded from outside, by the Medical Research Council, Institut Pasteur, US National Institutes of Health or Center for Disease Control.

The result, Corrah declared, was “The words that I hate most in medicine - ‘neglected tropical infections’. Why are they neglected? Because they are not easily transmissible, and are confined to Africa”. If an infection, such as Zika virus, spreads beyond Africa, there is an immediate, massive response, and containment is likely. But for those infections that do not threaten the North, “we need to establish our own research capacity, so we address these things while they are our problem”.

Building capacity requires more than just training PhD students, who remain handmaidens to research agendas defined elsewhere. It depends on creating opportunities to gain experience in the best centers in other countries, to develop as research leaders and, crucially, understand how to present ideas to funders. As he put it, “Lift that bright individual out, and they can develop the skills to win their own research grants.”

This was a further affirmation that mobility, of the right kind, is a good thing. But maximizing the benefits is not straightforward. Encourage visitors abroad to return, agreed Veugelers, but not too soon if your concern is capacity building. And individual research capacity won’t bear fruit in labs back home struggling to find the skills to maintain their stuff. “Sometimes the guy from Europe takes three months to come and fix your fancy equipment”, said Tumani.

A spell abroad is important in learning how to challenge elders, it was said. Cao believed it is still very difficult to question senior professors in China, especially if a researcher returns to their alma mater. But things are changing. The government now mandates retirement at 70, and the average age of Principal Investigators is currently falling by one year, every year. Still, Zhang judged, there is sense of “wait your turn” there when it comes to funding new projects.

As ever, there is a balance to strike here, and other angles to consider. Schlegel observed that one can also learn from the respect for elders evident in China, and that in any case there are hierarchies in every region. Nowotny noted the limitations of encouraging individuals to question established wisdom - the idea needs to be institutionalized, as historical examples such as the foundation of the College de France demonstrate.

As all this scientific travel broadens minds and prepares them to cultivate new ideas, how will the overarching story of science - if there is one - shift as cosmopolitanization moves on? Scientists are by nature global citizens, it was said, but we begin to see how there can be different ways of expressing this. This may involve taking a more critical look at Western discourse, said Schlegel, but, “it’s not so much about creating another single narrative, but creating space for the co-existence of narratives.” Just as clinical researchers have learnt that good studies need to include all types of patients, so diversity of perspectives will improve the outcomes of science.

At the same time, she emphasized that diversity needs to go along with shared principles, and there is work to do in establishing a process to help define them. “The big governance issue is how we create, or co-produce, global principles and values”.

3. Toward governance of globalized science

Pamela Andanda highlighted two exemplary projects that lay the groundwork for some aspects of governance of science and research in a more plural, geographically and culturally diverse global research system. As long ago as 2009 the European Commission published a working group report on Global Governance of Science (details here https://ec.europa.eu/research/science-society/document_library/pdf_06/global-governance-020609_en.pdf), covering matters including ethics, open access and openness to insights from other disciplines. One relevant recommendation, for example, was that research projects, including collaborations with scientists from other countries “should seek ways to enact basic fundamental rights of dignity, freedom, equality, solidarity, citizens’ rights, and justice in ways that also seek to respect and learn from the social and cultural contexts of non-Europeans – by, e.g., expert and public deliberations that develop and apply ideals of reconciliation.”

A more recent Horizon 2020 project, TRUST (http://trust-project.eu) develops one element of this, practical models to improve adherence to ethical standards worldwide. The team developed guidelines for global, inclusive and fair research, drawing on work with the San people of Southern Africa and with sex workers in Nairobi. Resources derived from this include a global code of conduct for research in resource poor settings, based on four key principles - fairness, respect, care and honesty - all geared to successful co-production with those in the community involved. There is also an interactive online Fair Research Contracting toolkit. (See http://frcweb.cohred.org). Andanda suggested the project shows the need for new forms of engagement with diverse groups, that produce a genuine exchange and “allow appreciation of local differences, local values and local knowledge”.

Science as a means to an end, but always with quality control

Flavia Schlegel developed this point in the context of the Sustainable Development Goals, the first globally agreed agenda that explicitly mentions ST&I. They incorporate a view of science as a means to an end, rather than a value to be protected, and underline how the governance challenge is becoming more complex - "multi-polar, multi-stakeholder and multi-level". She saw a need to strengthen regional governance entities, and to draw new actors into whatever structures are laid down. Success would be evident if the output of any process is relevant to the people who should profit from the research agenda in play.

Wei Yang, reflected on China's rapid growth, and how success in expanding their research system highlights the need to maintain quality as output increases. This has been addressed by shifting emphasis from quantitative to qualitative metrics - with university promotions depending on more than bean counting - and by encouraging international collaboration. The National Natural Science Foundation of China (NSFC), which he served as President, has overseen a ten-fold increase in the budget for international collaboration in the last 11 years, and the number of Chinese authored papers with international co-authors has increased even more.

There is also a multi-pronged effort to reinforce research integrity, ranging over education, regulation and strong action on the part of individual institutions. In 2015, when scores of Chinese authored papers were retracted by major journal publishers who uncovered fake peer reviews, the response was thorough: "We investigated all the cases that involved NSFC, called back all related funding, set up embargo periods for grant applications, and disclosed to the public the involved personnel and institutions. We called two press conferences to announce the investigation results". China also contributes to the Global Research Council and the World Conference on Research Integrity, as suitable fora for "top down" recommendations on research integrity.

Zhang wondered if it was time to work more on discourse and culture in China, move beyond simple concerns with plagiarism, and "raise the bar" on research ethics education in China. In her experience interviewing scientists in China about research ethics a common response was "we're fine because we don't copy anything", suggesting that they needed to broaden their thinking about what might amount to compromising scientific integrity.

Magdalena Skipper, Editor-in-Chief of *Nature*, agreed that integrity is fundamental and has to be part of researchers' identity. Researchers work to find out how the universe works, which leaves no room for malpractice. It is also important to recognize the crucial difference between having integrity and being incorrect, and not having integrity and trying to fabricate or manipulate data. And she added: "Don't lose sight of the fact that an important part of science is to be wrong – and then correct it!"

As far as ensuring research integrity goes, journals have an important part to play, and are already doing so. For example, *Nature* has worked on ways for researchers to report on their results in a transparent way, including reporting summaries tailored to different disciplines. There is evidence now that these are informing design of experiments as well as shaping how the results are presented.

Max Voegler agreed that research integrity is something publishers are working on, both through policies and through technology. For example, there is work to develop an image corpus to aid detection of re-use. As well as journals' own interest, it is important

for science as a whole, as part of retaining public trust. In that regard, funders and publishers are similar, he said. “They are gatekeepers and quality assurance instruments for the larger scientific enterprise, nationally or internationally - offering, if not governance, then certainly guidance”.

Bourguignon endorsed the importance of vigilance for research misconduct: “You just need one bad case to kill thousands of efforts to create trust”. However, funders’ can only do so much. They may rely on contracts with institutions who provide assurances that they have the right systems in place. The European Research Council, for example, has no investigative powers, so may occasionally discover that “this structure that exists on paper does not exist in reality”. Nor does it help that regulations differ from country to country.

Potthast emphasized that, among the various ethical considerations in play, it is important to identify some ethical universals as global science diversifies. In particular, there should not be any variation in what counts as fraud, or fabrication or falsification of data because “this is universal”.

Maintaining the free flow of people, and knowledge

Assuming the conduct of the research is sound, and the data valid, there are additional considerations in ensuring that everyone who needs it can access it, and in making sure researchers can move with as little restriction as possible to enrich their experience by working in different countries.

Veugelers stressed the importance of gathering better comparative data on movement of people. However, small surveys indicate that the main motivation for moving is the quality of the research environment, while other technical and legal barriers are relatively unimportant. So it is the quality of science systems that generates mobility. Schreiterer agreed, emphasizing that international mobility of scientists is to a large degree self-organized, and people tend to go to places or people that they know are the best.

Sam Gyimah, Minister of State for Universities, Science, Research and Innovation in the UK, stressed the UK’s commitment to ensure it can still benefit from incoming talent post-Brexit. More broadly, he was concerned that a rise in nationalism and protectionism could encourage immigration policies that discourage movement of scientific talent. Guarding against this might also be compromised by under-appreciating the value of science in a world of fake news.

Nowotny warned that there is already a problem in many countries with visas to attend a conference. “This really cuts into the lifeblood of science and makes the circulation of ideas impossible”. She suggested that ministers for science were well aware of this, but interior ministries fail to recognize that scientists and researchers are a category that needs to be recognized. “Some important voices in science should really get up and say that this is unacceptable.”

When it comes to flow of knowledge, Andanda raised a concern about the corporatization of academia. Over-reliance on indicators, especially the number of publications, is an obstacle to sharing quality. And proprietary claims on knowledge are “a huge barrier that people are too shy to talk about.” This can even affect data sharing within the same institution. At a higher level, it was important to seek convergence between departments of government. Departments of trade were prone to set up bilateral trade

agreements that impose data restrictions. Science and education departments would take a different view.

Movement of people, *and* data

Data sharing also raises delicate issue in some cross-national collaborations. Corrah pointed to “a fear amongst African researchers who collect data and don’t have the know-how to publish beyond a local journal.” The worry is that an overseas collaborator arrives and does a more sophisticated analysis, and the person who supplied the data ends up far down on the author list on a higher-profile paper.

There were several answers. Dissuade people from hoarding data by training them to analyze it fully, and publish, said Corrah. Make sure we value the data-generator, suggested Skipper: “The onus is on us as researchers, and publishers, to surface these different functions”. It is an ethical question perhaps, suggested Aina. We need to consider how we organize recognition, and what governs the nature of acknowledgment or the ordering of names on a publication. Nowotny recalled that in some disciplines it is possible to mandate local collaborators in fieldwork. But it is still wise to ask if globalization is always good from a developing country’s point of view. And Zhang pointed out that Chinese universities encouraged scientists to publish in English language journals, which hampered industrial translation there because companies did not read papers in English.

All of this also underlined the importance of the movement for open data, where support from funders and journals remains important. There are moves toward sharing knowledge about knowledge sharing - UNESCO’s Global Open Access Portal (http://www.unesco.org/new/en/communication-and-information/portals-and-platforms/goap) has information on 158 countries’ approaches to open access, but there is still scope for cataloguing and codifying what works best so funders can see if they are following best practice.

A key issue is allowing for the costs of the necessary follow-up. Binding researchers to open data protocols incurs obligations for curation and transfer of data, which carry time and resource costs. As Voegler noted, “both curating data and doing the compliance work afterwards is a lot of work, so it is a significant challenge to fund it.”. In addition, lab practices are highly disciplinary specific, so it will take time for each disciplinary community to find ways to adopt and adapt good practices for open data.

4. Final discussion

The hazard of considering science, research, and institutions on a global scale is that you may be tempted to try and discuss all the problems of the world at once. To keep things within bounds, moderator Vivienne Parry invited everyone to focus on one of three big questions that ran through the entire day.

- How to ensure there are global research standards in ethics?
- How best to remove borders and barriers and increase free flow of people and knowledge?
- How to share scientific progress globally, and use it to tackle the grand challenges that face the entire world?

This was still a pretty broad canvas, and suggestions and comments ranged widely.

To shore up ethical standards in research, start by embedding social and ethical issues in all science education, suggested Zhang. This is needed in all countries, not just those coming to a stronger presence in science. People need to be convinced that ethical guidelines are not a bureaucratic burden, but help them navigate the uncharted territories of science, said Andanda. More broadly, paying real heed to the Universal Declaration of Human Rights would improve matters across the world, observed Schlegel.

Publishers and funders need to work together more to align their policies on integrity and research data, as an aid to compliance, proposed Voegler. However, Schreiterer was content that work on research integrity and preventing misconduct is already well under way. Not much needs to be added, as scientists are clear about their own self-interest in avoiding the taint of misconduct. There is an inherent self-regulation there that is powerful.

On free movement and transparency, Skipper underlined that free flow of knowledge underpins answers to all three of the big questions. In the journal sector, funders and publishers need to get together to produce infrastructure - and incentives - and then mandate sharing of data, materials and protocols. Genuine open science along those lines “can then truly inform and benefit science globally, regardless of where the information is generated.”

Yang cautioned that open data can’t be instituted from the top down because governments don’t necessarily want it. It is best accomplished bottom up, by researchers who want to share their data with a global community. So their path should be smoothed by ensuring supporting data increases their chance of publication in good journals, and that the formats required are user-friendly.

On securing global benefits, it was suggested that the way forward in relation to global challenges is best charted via co-production, and requires transdisciplinary approaches. Metrics that register institutions’ or research groups contributions to defined global challenges could help: “Metrics sharpen the mind”. Rizzuto wondered if there could be a way to implement sustainability accounting for research projects, as a complement to conventional accounting for expenditure. Nowotny suggested that journal papers might be accompanied by a new lay abstract, aimed at a particular community, that explained the possible benefits of their work, however distant. “If done systematically”, she urged, “it would help tremendously to increase researchers’ awareness.” Aina wanted to explore better ways of recognizing people working to develop science for public good, across generations - perhaps with an appropriate prize.

On the other hand, emphasizing benefit to humanity at all levels of the research system might be to confuse research with development. And, as Schreiterer noted, there are cautionary tales from the history of science in which focus on practical results has opened a path for ideological influences, and to political elites telling scientists what to do. “We need to ‘de-moralize’ science, he suggested. It is fine to try nudging science in more beneficial directions, but requiring impact assessments is not the way forward. Be content with incremental change, and offer funding for grand challenges: “Money is where scientists go. That’s a political decision.” Veugelers agreed that money is the strongest incentive, and advocated bottom up funding of the best ideas, selected by peer review. Her general prescription might appeal to some as widely applicable in science policy, whether global or local: “Trust the researchers; take a bit more risk”.