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Finding Safe Zones for Science

Serious cooperation between US and Chinese scientists is getting more difficult as geopolitical tensions increase. But with a deliberate strategy the two countries can realize massive potential gains.

For those of us engaged in international scientific collaboration, today's geopolitics are starting to rhyme with history. In the 1960s, US and Soviet scientists sought new ways to collaborate despite deteriorating political relationships. These opportunities required navigating real and imaginary national security concerns. In the 1980s, it was Japan that offered a myriad of opportunities for cooperation with US universities, at a time when that country's growing strength was seen as a competitive economic threat.

Today the rising power is China. While opportunities for the United States to work cooperatively with China are immense, so are the challenges as the two countries are competitors across many dimensions, encompassing both economic and national security. Still, the lessons learned from Soviet and Japanese collaboration can help shape a practical US-Chinese strategy. And what we learn working with China should shape the next frontier of international cooperation decades hence—with a rising Brazil, a resurgent Russia, and other ascendent powers.

The opportunity to collaborate with China is clear enough. Both countries are powerhouses in global high technology manufacturing: the United States produced 31% and China 21% of a global total of $1.6 trillion of high-tech products in 2016. Yet their very success economically puts them into direct competition. Scholars estimate that import competition from China eliminated 2–2.4 million US jobs between 1999 and 2011, mostly among less skilled workers.

Thanks mainly to the rise of China, the two nations also now compete in basic science, a source of future economic growth. China boosted its research and development spending by 18% per year between 2000 and 2015; today, rising from a mere margin, the country accounts for 21% of global R&D. By contrast, the United States has expanded basic research investments by a paltry 4% per year, a rate that matches the world's growth rate but keeps the US share of the global total stuck at 26%. In 2015, Chinese innovators filed almost double the number of patents filed in the United States. And in 2016, China overtook the United States in terms of total scientific publications and now leads the world in top citation counts in some critical fields such as advanced materials.

Technologies such as artificial intelligence and cybersecurity, which might have otherwise opened opportunities for collaboration, now stoke adversity because they can be applied to weapons and cyberespionage—giving their development the flavor of an arms race. In cybersecurity, for instance, it is hard to distinguish between offensive and defensive moves, and in an atmosphere of mistrust, responses and counterresponses make it ever harder to return to a cordial relationship. These tensions do not yet amount to a new Cold War, but their persistence corrodes goodwill between the two countries. Despite all these challenges, the potential gains from collaboration between the United States and China remain massive and, plausibly, will get bigger as each country advances.

It is no longer good enough for the scientific community to merely declare that there are big gains from collaboration. Abstract gains often don't carry much political weight, especially in the context of deep mistrust. We in the scientific community must get better at managing collaborations to align with geopolitical realities and risks. We must pick and choose among opportunities that aren't prone to toxic geopolitical spirals. Where cooperation requires bigger geopolitical risks, we must have structures and strategies that lower the risks. These strategies for engagement must be based in reality and built to survive inevitable ups and downs, not just justified by abstract and theoretical gains.

Creating an agenda for collaboration won't be easy, for the political context that has underpinned such efforts in recent decades is quickly eroding. Internal politics in both nations now rewards hostility, making it even harder to mount and sustain efforts aimed at stanching today's wounds. Here in the United States the pressures to avoid cooperation are bipartisan and growing in intensity. In fact, one of the few areas of continuity from the Trump to the Biden administrations has been ever-frostier relations with China.

To help address this situation, we propose a framework for thinking about where US-Chinese research collaboration, in today's tense environment, can most usefully and most practically occur. Our framework helps to identify safe zones: places where traditional cooperation will be greatest. And it puts a spotlight on those places where gains, while potentially large, are steeped in political risk. The hard but most fruitful work of collaboration will come in those places—but only with active political engineering to help manage the risks.

It is one thing to offer an idealized scheme for focus, but quite another to put that system into practice. Thus, we also offer an outline of US science and technology (S&T) policy that can facilitate cooperation, and we invite a comparable effort in China. With such support, deliberation by practical-minded scientists, technologists, and research administrators in both countries can help their governments coordinate joint action.

A framework for cooperation

The centerpiece of our argument is a framework for identifying areas that have the potential for large gains and where cooperation—intrinsically or with policy design—can be buffered against inevitable geopolitical shocks. In the next 75 years, learning how to achieve and sustain these gains from cooperation will have many advantages. By expanding the domain of ideas and the size of markets for experimentation, cooperative approaches can push the technological frontier faster and allow more rapid and pervasive scaling in the application of novel technologies.

This wave of cooperation could give the United States a stronger hand in shaping standards and norms for technologies that could go awry, such as artificial intelligence and solar geoengineering. And cooperation, where it works, can cultivate goodwill that can help the two countries through periods of geopolitical tensions and form a basis for broader mutual efforts. During and after the Cold War, scientists who had cooperated across the Iron Curtain helped their countries navigate difficult issues, just as scientists with similar histories helped the United States and Iran reach a deal on the latter's nuclear program even as the two remain at loggerheads on many other issues.

Only a decade ago, when the United States and China weren't steeped in suspicion of each other's intentions, it might have been possible to identify areas where there would be gains from collaboration and to get started on building them. At that time, economic or scientific shocks could have been tamped down. Today, much more careful design of cooperative policies will be needed, and we must anticipate storms that could blow plans off course. A realistic S&T cooperation policy, advanced in the context of low levels of trust, requires that the scientific community and its allied diplomats get better at understanding where debilitating shocks may arise and how to manage their fallout.

The framework in Table 1 maps two dimensions of possible outcomes from potential US-Chinese cooperation in particular domains of science and technology.

One outcome, displayed on the horizontal axis, is possible joint social gains from cooperating in contrast to a scenario in which each country works independently. Along the scale of gains, we expect mature technologies and scientific knowledge, along with innovations closer to commercial application such as wind energy or aerospace technology, to yield low gains from cooperation. These fall on the left half of the table. By contrast, activities that fall on the right half, such as fundamental research, offer, in our estimation, clearer potential for gains. In this domain are areas in which neither country has a clear lead or projects are complex and expensive. Such areas are likely to generate large spillovers that, because they are difficult to appropriate, benefit from recombination of diverse ideas and market pull at scale. These potential shared interests could also make the relationship more resilient to future political shocks that can undermine practical cooperation.

The vertical axis shows the risk that collaboration could spark or intensify political tensions. Bilateral relations are always perturbed by events; what matters is the capacity to contain the political damage and sustain valuable interactions. For instance, the US bombing of the Chinese embassy in Belgrade in 1999 rocked the relationship, at what was otherwise a relatively high point. Protesters stormed the US embassy district in Beijing, but the tensions abated when a compensation agreement was later drawn up. Collateral

Table 1. **FRAMEWORK FOR ASSESSING TRADE-OFFS IN JOINT SOCIAL GAINS VERSUS POLITICAL RISKS IN US-CHINA COOPERATION**

RISK OF COOPERATIVE ACTIVITY MAGNIFYING ADVERSE POLITICAL RELATIONS		
INCREASING	• Advanced weapons systems • Machine-augmented intelligence • Aerospace technology • Quantum encryption • High-voltage direct current electricity transmission • Small modular reactors and micro nuclear reactors	• Joint investigation of COVID-19 origins • Earth observation, e.g., greenhouse gas emissions, climate change, human trafficking, environmental degradation • Superconductivity • Geoengineering • Stem cell research
DECREASING	• Wind and solar energy technology development • Advanced battery chemistries • High-speed rail	• Radio and optical astronomy; astrophysics • Solid earth physics; plate tectonics; systems ecology • Advanced mathematics • Carbon capture and sequestration • Fundamental quantum physics • Technical standard-setting

INCREASING →

ANTICIPATED JOINT SOCIAL GAINS FROM COOPERATING

damage to the long-term relationship was contained, and relations were normalized—including, in 2001, when the United States backed China's entry into the World Trade Organization.

Today, relations are less stable, and collateral damage is harder to contain. A variety of possible shocks—such as a major computer or biological hacking event, a military escalation in the South China Sea, metastasizing anti-Chinese racism in the United States, or dramatic financial losses in world stock markets linked to heavy-handed government interventions—could quickly scuttle fragile support for ongoing or potential cooperation. These sorts of shocks will put any collaboration agreement at risk, but if the agreement itself generates or exacerbates tensions, cooperation is unlikely to take hold and be fruitful.

Fallout is likely to be lower if the collaboration generates powerful stakeholders in both countries who want the effort to continue or if domestic interests in both countries don't much care about the domain of cooperation. Fundamental work in quantum and particle physics, for example, could distribute high fixed costs while generating new knowledge. Potential fallout increases if joint research products have applications in areas that are primed for contestation, real or perceived, such as national defense or economic competitiveness.

As technology development advances, the opportunities and risks from cooperation may shift. More fundamental research domains, long thought to occupy a benign world of apolitical thinkers, may migrate northwest in the framework. For example, some advances in solid earth physics (lower right quadrant) could inform the design of guidance systems for missiles (upper left quadrant). Uneven advances within each country could yield more benign shifts. For example, if carbon capture and sequestration or direct air capture technologies advance—as has happened in wind power—that might limit the potential for joint gains from continued cooperation. Shifts that cause a technology to migrate from the lower right to lower left quadrants require rethinking traditional S&T collaborations but are unlikely to poke the geopolitical bear. In the United States, some will fear that China's innovators may be able to move more swiftly, and with state support, to capture market share; but that risk exists even if innovation proceeds independently. The case of lithium-based batteries offers a current example: because China (along with Korea) dominates the field, cooperative efforts to advance even fundamental research in this area are viewed with skepticism.

Outlining a policy strategy

When used to inform policymaking, the implicit message of our framework is that successful collaborations must start with a wisely chosen domain. Regardless of the personalities of scientists or institutions involved, the determining factor in long-term scientific cooperation will be the ability to generate mutually beneficial gains while lowering the risks from geopolitical shocks. This context varies with different concerns and technologies.

Cooperation is likely to be most politically viable and durable if focused on the activities that sit in the lower right quadrant of the table. These are activities that create hard-to-appropriate fundamental knowledge or hard-to-realize resource-intensive demonstrations of technologies that have the potential to improve the human condition. In areas of fundamental science ranging from basic biology and genomics to radio astronomy, gravity waves, and the study of neutrinos, Chinese research is strong and growing and ripe for a mutually beneficial collaboration with the United States.

One example of technology demonstration can be found in the US-China Clean Energy Research Center (CERC)—a consortium created during the Obama administration as part of a comprehensive strategy to link the two countries more closely. CERC facilitated productive interactions between academic and industry researchers focused in thematic areas such as cleaner coal and green buildings, generating publications, patents, networks, and goodwill, and helped to manage potential intellectual property conflicts. Had CERC been bigger in scale and more reliable in its commitment, the impact probably would have been much larger, with higher odds of joint discoveries that could cause fundamental shifts and commercial applications of clean energy technology at scale. Such engagement with China around advanced technology and deployment might also have made it much easier to help shape that country's massive energy technology export program linked to the Belt and Road Initiative.

It may be possible to maximize gains from cooperation by navigating around areas of toxic fallout. For example, rather than launching a collaborative study on the origins of COVID-19, China and the United States could establish a joint research program to control future zoonotic diseases that could lead to global pandemics. However painstaking, this process could successfully move this sensitive area from the upper right to lower right quadrants in our scheme.

Collaborations outside the lower right quadrant in the framework will demand utmost tact in their management. The area where strategic thinking is most important is the upper right quadrant, featuring areas with large potential gains from collaboration, despite high risks. Work undertaken in this quadrant requires a degree of "political engineering"—ensuring that collaboration generates domestic benefits for a powerful constituency and thus guaranteeing political supporters that will sustain the enterprise through rough periods in foreign relations.

Such an engineering of political support for a research program has precedent. The US Department of Energy's programs on carbon capture and sequestration (CCS), for example, have shifted from integrated cross-border activities when relations have been good to separate but coordinated activities when relations turn rough—all the while continuing to deliver benefits. The Advanced Coal Technology Track of the CERC created opportunities for top CCS researchers and industry practitioners from both countries to interact regularly and develop joint projects, part of a longer history of US-Chinese collaboration on energy. The cooperation built on and reinforced over 15 years of research funded by DOE and spread across the country, from West Virginia to New Mexico, with local academic and industry partners. The program survived renewed US-Chinese tensions under the Trump administration. Although it has not been renewed post-2020, the groups it funded in both countries will continue research with strong domestic backing—and establish a foundation for restarting practical collaboration. Pressure to deliver on decarbonization will push innovators in both countries in parallel, with the result that any progress is likely to continue and to deliver associated benefits. Governments can't orchestrate that fully, but their actions can raise the odds that innovators will find partners and their joint efforts will thrive.

The most problematic domain for collaboration involves topics that fall in the upper left quadrant of the framework. Here expectations should be lowest, though there remains merit in monitoring opportunities closely. Without access to classified evidence, it is unclear to what extent US concerns about the telecommunication systems being supplied around the world by China's Huawei are motivated by legitimate security concerns (hidden software capabilities) and to what extent they reflect a desire to advance the commercial interests of American competitors. Such potential risks of hidden security vulnerabilities are real for high-voltage circuit breakers, transformers, pumps, valves, and other critical devices in networked systems, all of which are now integrated with digital control and communications systems. "Proving" all the associated code, to make sure there are no hidden traps, is probably not possible, but the computer security and regulatory communities should be working harder on developing strategies that can dramatically reduce our vulnerabilities.

Beyond specific technologies

In the real world, cooperative action often does not sit neatly in just one of the quadrants. Rather collaboration in one domain is frequently linked to others, and, as noted above, cooperation that begins in one quadrant can migrate to another. What seems like a low-risk venture at one time may become embroiled in controversy as the relationship between nations sours. The task is therefore to figure out how to avoid global bifurcation in areas where the gains from cooperating are highest while taking clear-eyed steps to address potential security threats. Civilian space programs offer an excellent example. Today, in part because of an early congressional ban on all forms of US collaboration with China in this domain, the world is witnessing the development of parallel programs to build space stations and lunar bases. Rather than the ongoing competition, it seems likely that a collaborative international program could be achieving much greater benefit for all.

Supply chains provide a good example of the multiquadrant nature of real commercial and S&T activities. One of the many lessons of the pandemic has been that supply chains built for economic efficiency can quickly break down when circumstances change. The narratives we have generated around such interdependencies need to be re-examined. Supply chains that are critical require careful management and international cooperation. We know, for example, we will continue to need advanced semiconductors, power electronics, high-performance batteries, civilian aircraft, and large high-voltage circuit breakers and power transformers. For these technologies, national security hinges on understanding the geography of supporting supply chains in detail and building redundant pathways for critical components.

In some cases, redundant production in friendly countries plus domestic stockpiles will be sufficient. In other cases, identifying supply chain vulnerabilities and reducing them in a sustainable way may be challenging. Two years ago, public health officials found it hard to persuade policymakers that the United States had a vulnerability in the supply of personal protective equipment (PPE) and ventilators. Shortages and skyrocketing prices in the early months of COVID-19 proved the former vulnerability correct and the latter obdurate. The lesson is that US policy should value resilience in critical supply chains more highly—to incentivize investments in flexible capacity and ensure that stress testing for resilience occurs alongside commercial pressure to optimize efficiency. As system ecologists have told us for years, there is an inherent tension between resilience and efficiency. If an environment is very stable, it is expensive to maintain capabilities that will only become important when the environment changes.

Flexible manufacturing capacity is thus paramount. A nation does not have to be making or stockpiling lots of ventilators if it has supported the ability of its manufacturers and suppliers to rapidly pivot to provide them when the need arises. However, developing this capability is more than a technical problem. It requires coherent and supportive public policy and regulation to make it economically viable for private sector players to invest in production flexibility to support resilience. Stockpiling has a role, but what really matters is a stockpiling strategy that is informed by frontier information about how quickly and flexibly production lines can pivot and scale as needed in extreme circumstances. In the era of global supply chains, no government can make those policy choices independently.

A similar shift in interdependencies can be seen in frameworks for dual-use technologies and export controls, which now seem outdated. Determining when restrictions apply to a specific technology is challenging. For instance, we have placed "fundamental quantum physics" in the lower right quadrant of the framework and "quantum encryption" in the upper left because we can see basic ideas in the former and national security application in the latter. But some forms of progress in quantum physics could quickly upend the implications for encryption and other applications. There will always be those in the security community who will argue that any area that could in theory lead to national security consequences should be controlled.

An expansive interpretation of dual-use technologies will, over time, isolate the United States from ideas and capital in the rest of the world. An example of harmfully expansive definitions is when the Committee on Foreign Investment in the United States, headed by the Treasury secretary, rejected a China-linked company's bid to invest in US wind farms. Similarly, for years the United States banned the export of higher-end encryption technology needed in the financial industry. The result was that European suppliers moved in to fill the need, using knowledge either available in the literature or that they had independently developed, and the United States lost much of that market. Keeping export control systems efficient and up to date will never be easy, but a failure to devise much better and balanced strategies can have serious consequences for the competitive position of US industry.

As with export control, the development of commercial standards is an area that, if handled poorly, could impede cooperation. The standards to which products and processes are designed and certified may strike many as dull or obscure, but they are critical to modern technical society and can underpin national competitive advantage in subtle ways. China's government has figured this out and is working to establish standards that will advantage its manufacturers in both formal and informal ways. The Western democracies must engage more actively in preserving an inclusive, even-handed approach to global standard-setting for emerging technologies. There is considerable evidence that the best standards are those developed through negotiation among relevant experts and firms, *not* simply imposed by national governments.

A full-blown assessment of US export control, supply chain, and dual-use systems is beyond the scope of this article, but a few elements are clear. The United States has a great need for a cross-government strategy with a mandate to do a better job of balancing security with other important goals like economic competitiveness, integration, and access to the world of ideas.

Absent proactive and nimble policies in these vital areas of collaboration, the massive benefits of scale that come from a global perspective will be lost. Consider the challenges of the transition to lower carbon energy. Several profound revolutions have made solar power cheaper. The first began in the West with cooperation on solar research that generated ideas that, as happens with ideas, spread widely. A relentless drive to cut manufacturing costs in China, driven partly by large government subsidies, in order to sell to a global market resulted in a 90% fall in prices over a decade, making solar panels competitive, in some circumstances, with fossil fuels. A huge part of the value in cooperation around innovation comes from scale, and now that the system is fragmenting, solar power prices are rising again. The fracturing of the US-Chinese relationship reminds us that scale doesn't happen automatically and must be nurtured.

Science meets geopolitics

As we write, China and the United States are in the process of rewriting their national attitudes toward each other. The sense that we are again rhyming with history is getting stronger. A very similar recasting of national policy—and national biases against the people of other countries—occurred as contests heated up with the Soviet Union and Japan (and with other countries even earlier). Hearing rhymes can be instructive, but our policy responses need not echo the past, especially when those echoes prevent us from recognizing what is different or how we can do better.

Scientists love global science because the search is expansive and the benefits are highly diffused. Witness the gains that have accrued globally—albeit unequally and unevenly—from investments, concentrated in the West, in basic research that have made novel vaccines for the coronavirus possible. Such global science cannot thrive without openness—freedom of ideas, people, and capital.

The story of post-World War II science is that such a diffusion of global benefits has not led to paralysis in policy because the benefits have been big enough that the risks have been politically tolerable. That idea was never really tested with the Soviet Union, even though there were some fragile bridges between Western and Soviet science and those bridges proved highly useful. The concept met another test in the 1980s with Japan and survived, in part because Japan's economy stalled.

The test with China will be much harder, although the benefits from successful collaboration may be significantly larger than anything previous efforts have offered. The political constituencies that must be satisfied to hold together scientific cooperation aren't global but national and local, and we must also create enough tangible benefits to keep scientists themselves engaged. The US government is now making it increasingly difficult for Chinese students in STEM to pursue graduate studies in the United States and stay here after they graduate. In some cases, administrators implementing US policy are hassling US investigators, especially those of Chinese origin, who collaborate with colleagues in China. China, meanwhile, is finding ways to keep its top graduates at home. These shifts are transforming what is possible for scientific cooperation. Failure to create a durable strategy for scientific collaboration could deprive both countries—and humanity in general—of the fruits of such joint efforts.

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RECOMMENDED READING

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