International collaboration in science: a new dynamic for knowledge creation

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Chapter II

Science and Foreign Policy: The Elusive Partnership

The collaboration started after the fall of the Iron Curtain, when Russians attended a world conference on virology. The Russian side especially had started this line of research in late 1980s or early 1990s, but when we showed an interest in it, the study was resumed. The animal experiments on virus variants were done in Russia and the molecular part of the research studies were done in Marburg. In Marburg, we could not work with animals with these viruses, but the Russians could do this research on animals, so this part of the research had to be done in Russia. The molecular techniques were more advanced in Marburg, so this part of the research was conducted in Germany. It was a complementary study.

—H. D. Klenk, a virologist interviewed for the project
The elusive partnership: science and foreign policy

Caroline S Wagner

Nearly ten years after Eugene Skolnikoff tagged science, technology, and international affairs the "elusive transformation," the relationship has evolved, but both policy communities remain dissatisfied with the linkages. This may be unavoidable. Science and foreign policy have very different dynamics: one is a networked, peer-based community that holds few traditions; the other is a hierarchy of relationships based on history, protocol, and tradition. Nevertheless, these two systems find that their interests are increasingly overlapping, as the foreign policy portfolio contains issues with a scientific component, and as science grows more international in scope and practice. This article seeks to explicate the foreign policy aspects of science: its policy motivations, structures, and processes, in an effort to explain at least one part of the partnership. Science represents a potentially powerful tool for improving international relations, and learning to use it may benefit both science and international affairs.

SCIENCE AND FOREIGN POLICY are uneasy partners. On one hand, science is a system that is tied neither to geographical borders nor to history. It is forward looking, peer driven, and thrives on upending its own tenets. It is a networked, merit-based system in which any participant can contribute equally, and where, at times, unlikely players can gain status and acclaim. None of these statements could be reasonably applied to foreign policy — a system based on hierarchy, history, political borders, and tradition.

On the other hand, scientific research is still paid for principally by national governments. They expect to gain international prestige (scientific prizes), trade competitiveness (innovative industry), and other benefits (security, health) for taxpayers as a result of these investments. When expedient, foreign policymakers expect to use science to serve policy: the signing of an international science and technology agreement between governments can sometimes signal the beginning of improved relations between former adversaries and open the door for other types of interaction.¹ Joint scientific projects such as the International Space Station or research in Antarctica are supported in part because they provide a high profile bond that creates political goodwill.

Eugene Skolnikoff, in The Elusive Transformation: Science, Technology, and the Evolution of International Politics (1994) suggests that advances in science and technology have brought changes to the international political system. They have contributed to a "profound evolution of the details and substance of national and international affairs," in general terms, affecting the balance of the portfolio of issues that face ministries of foreign affairs. He pays particular attention to these changes in security,
Science and foreign policy

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Economic competitiveness, and environmental issues. Many of these issues continue to grow in importance on the international scene, joined recently by the global fight against terrorism.

Skolnikoff notes that these two systems — foreign policy and scientific research — operate in an international practice space that is increasingly overlapping. This aspect of the relationship has continued to converge. Although these communities have different structures and functions, the foreign policy portfolio increasingly faces issues with a scientific component. A number of foreign policy questions, such as treaties to mitigate climate change, stem infectious disease, and regulate trade in genetically modified plants and animals, require cooperation between the foreign policy and the scientific community. These might be called the “scientific aspects of foreign policy.”

The scientific aspects of foreign policy include megascience projects, large-scale, equipment-based projects in which science has been mobilized to serve policy and scientific goals. These activities could include the Manhattan Project, the failed Superconducting Super collider, and the International Space Station. A number of activities with the countries of the former Soviet Union, including the US Civilian Research and Development Foundation (CRDF), a nonprofit charitable organization initiated by the US Government that promotes scientific and technical collaboration between the United States and the countries of the Former Soviet Union, also serve both policy and scientific goals.

These projects have been controversial among the scientific community, in part because they can target areas for funding without explicit reference to a peer-reviewed, merit-based process. Scientists can find themselves on the periphery of megascience decisions, or, as Daniel Greenberg (2001) has argued, facing a trade off between funding for a compromised project or independent “critical inquiry and the search for truth.”

At the same time that foreign policy is facing more issues with a scientific component, the scientific system is becoming increasingly international in its research interests and practices. As it becomes more global, science has attendant issues of governance, knowledge-sharing protocols, and varying approaches to priority setting where foreign policy experts can provide input. Funding decisions at the programmatic level increasingly consider the global nature of knowledge creation and the importance of linking with experts in other countries. These might be called the “foreign policy aspects of science.”

The foreign policy aspects of science are when, where, and how to link with scientists from other countries when it would enhance knowledge creation. In many cases, particularly when scientists from advanced countries seek to collaborate among themselves, the flow of knowledge and interrelationships is seamless: few bureaucratic or political obstacles obstruct these linkages. In fact, in many cases, linkages are encouraged by program managers in scientific agencies. However, when linkages extend to countries outside a core group of advanced countries, questions attached to visas for people and equipment, the co-mingling of funds, access to data, and the attribution and sharing of results can become issues that need help from foreign policy specialists.

The tensions that result from what could be termed a mismatch (gently) or a clash (bluntly) between political and scientific goals are the features that continue to make this relationship “elusive,” but they are also the reasons why these communities need each other. As the relationship evolves and issues are more intertwined, the skills that each system embodies could be useful to the other. However, at least in the United States, it is fair to say that these two systems have little understanding of each other, and that each is ill-prepared to deal with the increasing internationalization of science or an increased role for science in international affairs.

Understanding the ways in which these systems overlap, how each is changing, agreeing on terms, and gaining a joint understanding of how each functions would make each system more useful to the other. There is much work to be done in this area. This article takes on only one part of this task: describing government support for international science — those parts of science where an explicit interest exists for both the scientific and foreign policy communities.

What do we mean by ‘international science’?

Most funding for science is provided by governments and spent within national borders. Yet science is referred to as “the most international of activities.” What do we mean by ‘international science’? There appears to be some confusion in the use of the term: it can be used to refer to the political interactions of nations around scientific interests, or to the political origins of research practitioners. A third meaning is ‘universal’ in the sense that knowledge creation in science is independent of the political or personal attributes of those creating and using that knowledge. At times, the term could be inferred to carry all these meanings.
Jean-Jacques Salomon (1971) is among the first to address the question of ‘what is international?’ in science:

“Because of its objectivity, science is considered to be supracultural, untrammelled by the conflicts of values … Even the idea of national scientific communities is contradictory; there can only be one scientific community, which must therefore be international.”

Perhaps we are suffering from the limitations of language, but, even here, Salomon seems to be referring to the lack of political ties rather than to the fact that science takes place between nationally based individuals and institutions. Publications of papers, for example, are tracked by policymakers seeking to account for the results of research. Publications on the Web of Science can easily be tracked based on the national origin of the author — a reflection of the overall system within which the individual scientist is working, and the interests of the sponsors within that system in claiming outcomes.

In their book Denationalising Science, Crawford et al (1993) define “international” as “activities involving persons, equipment, or funds from more than one country.” They note that the term implies political interest and organization. To take one step back, the concept of the ‘national’ connotes political, economic, and geographic congruence. This would certainly carry over to descriptions of a ‘national science policy,’ or ‘national research and development budgets’ as these elements of policy are exported by groups such as the Organization for Economic Cooperation and Development (OECD).

The idea of the ‘international,’ at least as it first emerged at the end of the 19th century, was that interactions were possible among these political nations, and that groups from within these nations could work together under the political protection and support offered by the nation state. This concept is descriptive of science as it has been practiced over the past 50 years — nationally funded practitioners do seek to work with others under politically determined guidelines — but the application of the term requires a more nuanced understanding.

Crawford and Shinn (1993) argue for the use of the term ‘trans-national’ rather than ‘international’ to remove the political connotations of the latter. This approach has an intuitive appeal. It does appear that scientists create linkages independent of the political process, relationships that seem to ‘rise above’ nations and create a meta-network or a super system. Scientists, after all, are not seeking to establish political ties when they collaborate. However, the reward system for science is still tied to national interests. Thus the term international may still be preferable to ‘trans-national,’ since it includes within it the political interests as well as the sense of the ‘universal’ nature of scientific knowledge.

Even using terms such as national and international to describe science and scientific exchange assumes and acknowledges the political nature of these linkages. As de Solla Price (1963) says, the system of “big science” that emerged in the post-war era is a highly political activity. Crawford (1992) notes that a peculiar feature of science comes “from its being at the same time both national and international.” Funding derives out of a national political process, and the linkages among scientists serve the interest of science, yes, but they also serve the interests of the nation.

The networks established between scientists in different nations are both trans-national, in that they are outside national interests, and international, in that they involve actors from different nations. The knowledge created is universal in the sense that any knowledgeable and motivated person, regardless of political allegiance or personal attribute, can access this system and understand its processes and outputs. Thus the term international science can still serve until a better one is offered, even while acknowledging that it includes these overlapping and interrelated concepts of science in the national interest, as well as the universal nature of the knowledge created by the scientific system.

Types of international scientific collaboration

Science has a number of features that extend beyond national borders — knowledge is codified in journals that are available to anyone, researchers conferences in international gatherings, fellows travel to work in foreign laboratories, research projects often include foreign partners. Of these features, the aspect of science that has the most explicit intersection with foreign policy is government funding for international collaborative programs and projects. Examples of these have been discussed above; they include both politically motivated and science-driven activities. The extent to which collaborations serve both science and foreign policy depends on the nature of funding and support they receive and the avenues used to initiate, manage, and evaluate them.

Smith and Katz (2000) make a useful distinction among types of collaboration, one that can help us...
put international science in context for application in a foreign policy perspective. They describe three models: corporate partnership; team; and interpersonal collaboration. This is a way to differentiate among level, rationale, structure, ownership and benefits of collaboration. The three models are described as follows:

- Corporate partnerships are highly formal, 'means to an end' collaborations that are initiated by more than one group and have as a goal access to external resources. These are high profile activities, within which projects often termed 'megascience' would be included. Activities such as the International Thermonuclear Experimental Reactor and the Human Genome Project are examples.

- Team collaboration exists (in terms of formality) below the corporate partnership model in the Smith and Katz formulation. These have a formalized existence but are not defined as formal partnerships. A motivating factor for these collaborations is the need for multidisciplinary skills and experience. This concept is similar to the Gibbons et al (1994) Mode 2 idea of the rise of multidisciplinary, team-based research. Projects such as the Intelligent Manufacturing Systems Initiative and the Human Frontier Science Project are examples.

- Interpersonal collaboration is a diverse category with activities dependent on the personal relationships between researchers or research groups. They are not attached to a specific project or program but are ongoing and informal. Conferences, workshops, fellowships, and shared data are examples.

Table 1 provides a summary of these features as well as some examples of international science. The formality of the partnership in the Smith-Katz formulation has an effect on the availability of the research activities to foreign policy. Activities that require a large budget, government-to-government agreements, and that arise out of both political and scientific needs (such as Antarctic research or the International Science and Technology Centers (ISTCs)) are the most likely to interact closely with, and possibly serve, foreign policy goals.

Team collaborations, as well, particularly ones proposed at the political level and requiring special budgeting commitments (such as the Human Frontier Science Program) have overlapping issues with the foreign policy community, although they may be less likely to serve explicit foreign policy goals. As international science becomes less formal and more science-focused, the research activities are less likely to be accessible to policymakers, and less likely to serve explicit foreign policy goals.

If we apply the Smith and Katz formulation to funds supplied by government, we can make additional distinctions that help us think about and analyze international collaboration in a foreign policy context.

### What governments commit to collaboration

Governments commit two things to collaborative projects: shared resources such as government-funded laboratories and equipment, and funding. Funds for international scientific collaboration are allocated through formal and informal mechanisms. The extent to which projects would be available to serve foreign-policy goals depends on this distinction. Government funds can be characterized as dedicated to or formal, and spent on or informal, collaboration.

<table>
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<tr>
<th>Types of project (Smith-Katz)</th>
<th>Examples of International collaboration</th>
<th>Budget category</th>
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<td>Int'l Space Station; Human Genome Project; Antarctic Research; International Science and Technology Centers; International Thermonuclear Experimental Reactor</td>
<td>Formal, dedicated project listed in government budget</td>
<td>Policy directed</td>
<td>High</td>
</tr>
<tr>
<td>Team collaboration</td>
<td>Human Frontier Research Program; Arctic ocean temperature measurements; Energy efficiency and renewables project; infectious disease epidemiology</td>
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<tr>
<td>Interpersonal collaboration</td>
<td>Conferences, workshops, symposia; laboratory visits; fellowships; databases</td>
<td></td>
<td>Science focused</td>
<td>Low</td>
</tr>
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Table 1. Summary of characteristics of international science
Funds dedicated to formal collaboration are those committed in the federal budget to support specific programs. These include activities such as the United States’ John Fogarty Center at the National Institutes of Health, the Canadian National Resources Canada program to support international agricultural research, and the Japanese International Cooperative Research Project within the Science and Technology Agency. This category includes the funding of transnational programs or institutions where the pooling of national resources for a common purpose creates a supranational facility or staff such as the European Organization for Nuclear Research (CERN). Because these funds are visible within an official budget, they might be considered the ‘tip of the iceberg,’ or corporate partnerships, as illustrated in Figure 1.

Funds spent on informal collaboration are those that emerge from research activities where scientists link with foreign counterparts in the course of conducting research. These activities form the bulk of international science. This category includes the grant-based activities of hundreds of scientists, as well as training programs for PhD students and post-doctoral fellows. These activities might be considered ‘the bulk of the iceberg’ or team and interpersonal partnerships in the Smith–Katz formulation, illustrated in Figure 1. Most governments do not budget for these activities in a way that allows for ready accounting and identification of the international components of the research — the international activities are the outcomes of pursuing excellent science.

For most governments, the tip of the iceberg (official spending) is a small part of the total spent on international activities.5 Under the Smith–Katz formulation, these would be corporate partnership funds, committed within the political process to serve a number of goals, particularly those with both a scientific and foreign policy component, such as the aid provided by western countries to bolster the scientific enterprises of the former Soviet Union.

In a study on US government funding for cooperation with Russia, RAND found that an average of US$350 million per year was spent on that relationship during the 1990s, with about half of this serving foreign policy driven missions (Wagner et al, 2002a) The foreign policy driven missions include helping to retrain former weapons scientists towards civilian goals. The ISTCs, initiated by the US Government, are one example of such a program. They promote the nonproliferation of weapons technology of mass destruction through transition to other types of scientific research and development.

The funds below the waterline arise from scientist-initiated or mission-specific research, where scientific goals are a primary motivating force. To date, only the US Government has estimated the amount spent on activities below the waterline, this through the studies conducted by RAND, summarized briefly below. Whereas corporate collaborations are often ‘top down’ — government officials establish and oversee the activities — team collaborations are more often ‘bottom-up’ research project. In team collaborations, scientists choose partners and apply to government for research support based on the strength of the partnership and the excellence of the science.

Extrapolating from the US experience, it can be postulated that team collaboration is a much larger amount of spending than dedicated, formal cooperation. RAND’s findings suggest that US government-funded informal team collaboration may be as much as 20 times higher than the funding for formal collaboration. If, in the interests of a ‘back of the envelop’ estimate, the official figures collected by Canada from seven countries in their report on international cooperation science of about Can$625 million, were multiplied 20 times, we begin to see that the amount of funding being spent on international team collaboration (upwards of Can$12 billion) is very large indeed (Advisory Council, 2000). However, only a small percentage of these funds is available as an explicit tool of foreign policy.

Patterns of international science

Finding new ways to integrate or to communicate better between science and foreign policy requires understanding the global network that is created by collaboration. These linkages create what de Solla Price (1963) called “invisible colleges” of practitioners.

International collaboration can be tracked, if imperfectly, by counting co-authored papers with different national addresses. Governments and science policy analysts regularly conduct these analyses. Recent literature shows that international co-authorships are rising (Glänzel, 2001; Luukkonen

Figure 1. Distinction between corporate and other types of collaboration
et al, 1992; Schubert et al, 1990; Georgiou, 1998; Dore et al, 1998) Databases such as those maintained by the Institute for Scientific Information (ISI) contain data on the publications thousands of scientific and technical journals.

As measured by co-authorships, international collaboration has been rising significantly over the past 20 years. Figure 2 shows international co-authorships over time, comparing the rates of countries with large scientific enterprises.

When linkages are examined by country, the United States is the dominant partner for most of the scientifically advanced countries (illustrated in Figure 3) in part because of the size of its scientific enterprise. Canada, Japan, and the United Kingdom are the most frequently observed partners in collaboration with the United States.

To view relationships among other scientifically advanced countries, Figure 4 shows the co-authorship linkages without the United States' share of articles: the co-authorship relationships now appear more balanced (the scale is different in Figures 3 and 4). The data suggest that the United Kingdom, France, and Germany are attractive partners, and that they have a robust interrelationship as well. The scientifically advanced countries have relatively weak links with developing countries, but they appear to be growing (Wagner et al, 2001).

Another way to measure international collaboration is by collecting into a single data set the successful grant and contract proposals that state intend to cooperate with a researcher from another country. RAND has conducted this analysis for the United States Government using the RaDiUS database and other sources. By counting the budgets of projects in which the principal investigator planned to cooperate, the total amount of funding was about 5% of the US research and development budget, or US$4.3 billion in fiscal year 1999 (Wagner et al, 2000). Just over 50% of these funds are spent on multinational projects.

Both corporate partnerships and team collaboration are represented, although not all these activities are budgeted as formal, dedicated projects. Funds spent on a binational basis, those in team partnership and interpersonal categories, arise out of the funding commitments of agencies. On a binational basis, the US Government spends the most money on joint projects with Russia (Wagner et al, 2002a), Japan, Canada (Wagner, 1999), the United Kingdom, and Germany, but, for the most part, these are not politically motivated projects (Wagner et al, 2000).

Four reasons account for most of the cooperative activities:

- Sharing costs: projects in which the costs of the infrastructure are such that no one nation can afford to make the investment on its own. These include activities such as shared astronomical observatories, high-energy physics laboratories, and space exploration.
- Nature of the subject: projects in which the global nature of the subject lends itself to international cooperation, for example, ocean drilling, atmospheric monitoring, and arctic research.
- Self-identification: it is in the interests of scientists to work closely with excellent researchers located in foreign countries.
- Missions: if not motivated by any of these reasons, cooperation may meet the mission requirements of an agency (Wagner, 1997).

![Figure 2. Comparison over time and by country of percentage of all S&T articles that are internationally co-authored](image1)

**Source:** NSB (2000)

![Figure 3. Patterns of percentages of international S&T co-authorship among six leading countries](image2)

**Source:** NSB (2000)

![Figure 4. Patterns of percentages of international S&T co-authorship among six leading countries, removing the USA as a primary partner](image3)

**Source:** NSB (2000)
US Government agencies with the most active international linkages, in terms of both funds and projects, are the National Aeronautics and Space Administration, the Department of Defense, the National Science Foundation, the Department of Health and Human Services (which includes the National Institutes of Health), and the Department of Energy. These agencies spend between 80 and 90% of all funds committed to international cooperation in science and technology (Wagner et al, 2000).

**Role of Department of State**

Notably absent from the list of US Government agencies providing funds to international science is the Department of State (hereafter, 'State'). State maintains offices to aid international discussions about scientific cooperation, as well as offices that manage US participation in high-profile international activities, such as the Intergovernmental Panel on Climate Change. State is involved in negotiations, usually as part of a multi-agency team, when the US is involved in treaty-level commitments. In addition, it helps to transfer funds from science agencies to international programs, such as the contributions to the ISTCs in Eastern Europe. State has no funds in its budget to commit to research and development.

The role of State with regard to science may be shifting in the wake of the attacks on the United States of September 11, 2001. The relationships between the USA and its allies, particularly in militarily sensitive research, may be strengthened as R&D funds flow into these areas based on security concerns. As this occurs, the need for more explicit agreements about how knowledge is protected and shared will clearly become more important.

In addition, Ausubel (2001) has argued that scientists, reaching across international borders, can play a significant role in mitigating conflict. To the extent that this becomes a political tool used by the USA, targeted research collaborations may be formed with nontraditional partners, such as countries in the Middle East, in order to build trusting relationships across political borders. Management of these issues would likely fall to the State Department.

One tool that State has to reach these goals is the International Science and Technology Agreement (ISTA). State has responsibility to negotiate ISTAs ('umbrella agreements') when it is the consensus of Government agencies that an agreement may be useful to political and scientific goals. The US Government reported 33 active umbrella ISTAs in place in 2000. In most cases, umbrella agreements play a small role in the commitment of funds to international collaboration. In the case of the USA, such an agreement has no associated commitment to spend funds with the signing partners. The agreements are put in place to create a framework within which scientists may apply jointly for bottom-up research and development funds.

ISTA are signed at a number of levels within the Government below the umbrella agreement, however, and these are negotiated and signed at the agency level. Three agencies have independent authority to enter into ISTAs: Departments of Defense and Energy, and the National Aeronautics and Space Administration. The political goals of national governments and the mission requirements of agencies motivate these government-to-government agreements, which range from legally binding treaties approved by legislatures to letters of correspondence between agencies with no legally binding authority. ISTAs cover the 'tip of the iceberg' activities (Figure 1), and some team collaborations.

ISTA are signed between countries that have at least some scientific capacity and where formal partnerships are the more common type of collaboration. ISTAs may actually be an indicator of a divergence in scientific culture between the signatories rather than of convergence. For example, the USA and Canada (perhaps the most tightly-knit bond in international science) do not have a formal ISTA. The same is true of the USA and the UK.

Also team and interpersonal collaboration are heavily represented in collaboration between the USA and Canada and the USA and the UK. In other words, these are robust scientific relationships. In contrast, the USA is more likely to have ISTAs with scientifically proficient countries, where the establishment of a formal mechanism and recourse for discussion is needed as a framework for establishing corporate collaborations. This is true between the USA and Mexico, for example (Wagner, 1999).

Some ISTAs are never fully implemented because of a lack of funds from one or both signatories. Sometimes, an agreement is made to cooperate and an ISTA is signed to establish the parameters of this cooperation. In other cases, S&T projects take place without reference to an ISTA. In some cases, one of the partners in a discussion needs an ISTA to secure funding for an international project. In these cases, an ISTA may be in the political and scientific interests of both parties.

Although ISTAs are not a good indicator of

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**Scientists, working internationally, can play a significant role in mitigating conflict: targeted research collaborations may be formed with nontraditional partners, such as countries in the Middle East, to build trusting relationships across political borders**
scientific activity, they can be an important indicator of national interest in building bridges. For example, when other types of political relationship are under strain, a science and technology agreement can be a way to establish a dialog with another country on important subjects with low consequence to foreign policy. ISTAs also can be used politically to open discussions about the protection of intellectual property and the sharing of natural resources. These bridge-building exercises can help related discussions in trade and diplomacy.

Implications of linkages for foreign policy

The foreign policy component of science and technology is limited to a small part of the budgets of scientifically advanced countries. International science claims between 5 and 20% of the science budgets of most countries. Within this piece of the budget pie, the formal, policy-directed activities set aside to serve foreign-policy goals are a relatively small percentage. Some team collaborations can serve both science and foreign-policy interests, and the scope of these activities may be growing, with implications for participation by both science and foreign policy. Other activities, such as bottom-up scientific collaboration and mission-oriented research are not directed by foreign-policy goals, but these linkages can help create associations that improve international relations. Together, these activities make up a nation's contribution to international science collaboration.

The diffused and decentralized structure of science decisionmaking has restricted the ability of governments to use it as an explicit policy tool. This is particularly true in the United States, which lacks a coordinating ministry for science and where the foreign policy apparatus has little understanding of science. As a result, an explicit role for science in US foreign policy has been limited to the relatively weak tool of the ISTA, or to dedicated, large-scale projects that must first serve scientific goals and missions of US Government agencies. Despite calls from groups such as the National Academy of Sciences for the State Department to give more attention to science, a persuasive argument still needs to be made that a more centralized approach to international science would lead to better management.

The inability to steer S&T to foreign-policy purposes does not mean that international science does not present challenges and opportunities for policy. Quite the opposite. Billions of dollars of research take place on an international scale each year. Although these funds are usually provided by governments (organizations with a bounded set of expectations) the benefits are accruing without regard to political boundaries. Indeed, the benefits from distributed research (that part of international collaboration that appears to be growing most rapidly) are likely accruing outside the bounds of any single nation.

Nations may be benefiting from the changing dynamics of research, but an examination of the organization of science and foreign policy may be in order. The ability of governments to oversee, to track and monitor outputs and outcomes, to influence research directions, and to appropriate spillover benefits is surely reduced (or at least significantly changed) by distributed international research. The political and scientific interests certainly overlap around this issue.

The shift in the organization and management of science towards a distributed international system presents challenges for foreign policy. Ausubel (2001) noted: "Observers of the scientific enterprise broadly accept that science is international in scope and activity, and that international cooperation has always been intrinsic to it." Science may be international in scope, but the interests of nations remain within political borders.

As the extent of cooperation increases, and the ways in which science contributes to society grow more complex, a better understanding of the types of cooperation (their practices, beneficiaries, and knowledge flows) is needed if nations expect to continue to reap benefits from it. Representatives of the scientific community would do well to acknowledge and understand the realities of accounting to the political system for the outputs and outcomes of investments in science.

At the same time, better coordination among science-policy practitioners across nations may be beneficial to all parties. This is occurring in groups such as the Global Science Forum of the OECD. More coordination along these lines would aid the governance of controversial international science issues, such as genetically modified foods. Within such coordination groups, stronger links with the foreign-policy community would also improve the cross-fertilization of skills that each needs from the other.

Policymakers may wish to consider a joint science–foreign-policy effort to create and use a toolkit of management styles, practices, and agreements that better match the different modes of cooperation and collaboration in international science. In the process, scientists may pick up a few tips from the diplomatic core. In turn, foreign policymakers may find that, as they participate in global forums alongside scientists, they become more comfortable with, and find ways to use, the loosely structured, always changing and dynamic, network that is international science.

Notes

1. This was the case with the signing in 1973 of an International Science and Technology Agreement between the United States and China.
2. This is the opening line of a lecture given by Lewis Thomas in 1973.
3. The National Science Board Indicators, for example, report on countries' share of papers published in internationally recognized journals (NSB, 2000).

4. The term 'corporate' can cause confusion when used to apply to policy in the United States, because it is frequently used to refer to business interests. We will use the term 'formal' in discussions below to avoid this confusion.


6. The Institute for Scientific Information (ISI) provides the data resulting in the National Science Board tables on patterns of national publications. ISI can be found at <http://www.isi.org>.

7. RadUSE is a database developed by RAND that contains information on US Government research and development spending at the project level. More information can be found at <https://radius.rand.org>.

8. Within the Bureau of Oceans, Environment, and Science, the US Department of State has only a very small office handling international science and technology cooperation, one with no budget authority or jurisdiction to allocate funds to international projects.

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