Chapter 10

Effective international science, technology and innovation collaboration: From lessons learned to policy change

Aurelia Figueroa and Andreas Stamm
German Development Institute

The aim of this chapter is to glean useful lessons from the findings of the preceding chapters for effective and efficient governance structures in international science, technology and innovation (STI) collaboration to meet global challenges. Lessons are presented for each of the five governance dimensions: priority setting, funding and spending, knowledge sharing and intellectual property, putting STI into practice, and capacity building for research and innovation. Cross-case analysis draws lessons in each of these dimensions and offers initial conclusions on effective modes of governance in a variety of circumstances. In conclusion, the chapter notes progress made and new challenges.

10.1. Introduction

International co-operation is increasingly seen as vital in order to reap the benefits of scientific research, technology development and innovation (STI) in order to address global challenges. Global challenges call for urgent and effective international responses by research and innovation systems, for well-informed policy making and for broad-based deployment of knowledge-based solutions in the business sector and in society. This has been repeatedly stressed in the international arena, most recently by the World Science Forum in November 2011 in Budapest, which declared that "(t)he growing complexity of grand challenges including population growth, climate change, food supply, energy shortages, natural and technological catastrophes, epidemics, and sustainability require that the world's scientific establishment assume new roles". The declaration notes the emergence of a new multi-polar world of science, accompanied by the rise of new scientific powerhouses. It recommends better international co-ordination of research on global challenges and stresses the need to support developing countries in their efforts to build their research capacities.

By far the major part of the available resources for research promotion is still programmed, spent, monitored and evaluated at the national level (European Commission, 2008). In this regard, STI remains rather reluctant to be part of the globalisation processes that characterise many other areas. The reasons for this inertia can be found in severe legitimacy issues and a lack of incentives for policy makers to invest available resources in international projects that are not yet proven and are characterised by higher transaction costs and risks than national programmes (see Chapter 1).

Whether and to what degree the potential for international STI co-operation can be realised depends upon the modes of governance of international undertakings and the extent to which they lead to effective and efficient collaborative research. This has been the guiding assumption of this volume.

Research conducted with the aim of responding to global challenges differs from research in other STI areas in that it addresses global public goods and responds to problems that require urgent solutions. All of the cases analysed in the present volume are a response to some of the most pressing global challenges. In most of the cases, promoting collaborative STI is at the heart of the organisation's mission, or at least one of its basic elements.

Internationally co-ordinated or collective STI can generate advantageous economies of scale. This is especially valuable for research initiatives that require investments beyond what national STI budgets can support. Without the pooling of financial resources, several large-scale research infrastructures would not exist. Where high levels of required investments go hand in hand with high levels of uncertainty and possibilities of failure, pooling resources internationally also has an important element of risk sharing. In some STI disciplines, pooling of internationally available resources may not be indispensable to achieve results, but may significantly shorten the innovation cycle. This is the logic behind the "Apollo-project type" research undertakings proposed by some observers in order to give timely answers to global challenges, *e.g.* concerning climate change and clean energy provision (Friedman, 2005), for which time is a crucial factor in avoiding further worsening of the situation and the danger of system collapses. Others reject these ideas, arguing that they assign the state too direct a role and neglect the demand side of the innovation process (Yang and Oppenheimer, 2007).

Still, the pooling of financial resources is not necessary in all cases to address global challenges adequately. The history of science and technology shows that important discoveries and developments originated in single laboratories or in collaborative undertakings involving only a few actors, such as the development of the powerful fertiliser superphosphate in German and British labs in Germany in the mid-nineteenth century. So-called golden rice, a rice variety modified through genetic engineering to produce a precursor of vitamin A, and thus improve the state of nutrition in poor developing countries, was mainly a co-development of a Swiss research institute (the Swiss Federal Institute of Technology) and a German university (the University of Freiburg) (see Chapter 9). However, in both cases the developments were embedded in internationally available fundamental advances in relevant disciplines, such as soil sciences and plant nutrition in the case of the former and genetic engineering in the case of the latter.

The value of international co-operation in STI goes beyond the scaling up of financial resources. Economies of scope apply, as communication and co-operation among researchers and research groups allows for cross-fertilisation of ideas and intermediate outcomes of undertakings with common goals achieved in different ways. Research on innovation systems has shown that technological developments in national systems of innovation tend to be based on a limited range of alternatives; this reinforces incumbent technologies (path dependency, technological lock-ins), even if superior alternatives may be available. International co-operation significantly enlarges the range of available knowledge and competencies, often embodied in individual researchers or institutions. This broadens the scope for the creative re-combination of available factors and thus for innovation.

While conducting international research on global challenges offers a number of benefits, these come at a cost in terms of transaction costs and risks. Transaction costs of all forms (search, bargaining, and enforcement costs) rise not only with the number of actors, but also with the number of countries or the variety of institutional settings. Identifying suitable research partners with similar interests and complementary assets (knowledge, research infrastructure, etc.) is usually much easier in a single country. This is because the density of relevant knowledge – not only explicit, but also tacit – about research lines and interests, capability, performance and reliability of actors is usually much greater than beyond national and cultural borders. Additionally, when a STI project is sponsored by various sources, this often implies multiple reporting and evaluation requirements.

Countries' STI funding mechanisms may vary significantly (*e.g.* shares of institutional *versus* project funding) as may, for instance, rules for public-private co-operation or patenting regimes. Reconciling diverse regimes within a collaborative STI undertaking may require expensive and time-consuming search and communication processes. Related to these higher transaction costs in international STI undertakings is the higher risk of failure, first in the phase preceding the actual collaborative project, *e.g.* because all of the involved parties cannot reach an agreement. Second, international co-operation may fail in the course of the project because certain actors fail, free-ride or drop out. Effective and efficient governance modes that foster quality outputs help to ensure the continued involvement of participants and attract valuable new contributors as they demonstrate the value of the collaboration. It is for these reasons, among others, that the efficiency and efficacy of governance modes are a key element of successful international STI collaboration.

10.2. Key themes and lessons from the analysis

The research compiled in this volume helps to understand the nature of global challenges and the responses of STI systems. It sheds some light on good practices in the governance of international STI to meet global challenges. It also reveals the complex nature of this governance: in some cases, aspects of the governance mode may have positive effects on some elements of the innovation chain but lead to problems in others. It may therefore be necessary to deal with tensions and trade-offs. Recognising and balancing these benefits and trade-offs is an important challenge.

Several effective and efficient modes of governance were identified in the case studies. Some factors of a collaboration may present a challenge in terms of balancing two governance modes that may appear contradictory. However, this need not create an "either/or" situation. For example, a project may rely on both top-down and bottom-up agenda and priority setting, with benefits of each realised in appropriate circumstances. An example is the Clean Coal Centre Implementing Agreement (International Energy Agency, see Chapter 7), which draws on bottom-up input to define its agenda but makes final decisions in a top-down fashion. As this and other examples show, governance modes may be combined and used in tandem to achieve a balanced approach adapted to arising needs and the changing requirements in the life cycle of international collaboration. Flexibility in governance approaches is an advantage.

The following sections review the themes and lessons learnt from the case studies as analysed through the lenses of the five governance dimensions (priority setting, funding and spending, knowledge sharing and intellectual property, putting STI into practice, capacity building for research and innovation). Table 10.1 summarises the findings of each of the main case studies.

Prior to agenda setting: Mobilising actors, attention and resources for international STI efforts to meet global challenges

As mentioned above, there is no overall global organisation to support the globalisation of STI and the formation of knowledge networks across national boundaries, and it is difficult to generate and maintain interest among political decision makers and researchers regarding international STI co-operation to address global challenges. The case studies show that two factors can be helpful. First, high-level political commitment to address global challenges co-operatively or collectively through research collaboration; second, alignment of international co-operation programmes with national STI priorities. The first factor is clearly positive in most cases but rather difficult to achieve. The second factor, as will be seen, presents clear trade-offs.

One way to increase international STI collaboration to meet global challenges is to organise high-level political support, *e.g.* by embedding international STI co-operation in overarching processes and modes of global governance with high international visibility. In the case of environmental regimes, this may occur through agreements and related organisations such as the United Nations Framework Convention on Climate Change (UNFCCC) (as the International Energy Agency Climate Technology Initiative Implementing Agreement has done) or other relevant UN conventions.

The Global Earth Observation (GEO) Ministerial and Earth observation summits provide an opportunity for direct engagement with political decision makers. GEO had five ministerial-level summits in its first six years of existence. It has also been championed by leading Earth observation countries and organisations. This political support has facilitated

collaboration in a highly diverse initiative. It has also raised the profile of integrated Earth observations and positively influenced countries' awareness of the value of Earth observations for decision making.

One factor that binds participating countries and organisations together in international research on global challenges and mobilises joint efforts is a strong and specific mandate formally or informally given to a network or organisation by the international community. In this context "specific" means that the mandate for a policy field or global challenge is clearly given to a certain group of actors. This appears to enhance ownership and a sense of responsibility. A firm mandate at the outset of an international collaborative effort facilitates recognition and trust. It is a key element of an effective foundation for international collaboration.

In the case of CGIAR, the international community provided a mandate for the conservation of the world's genetic resources of major staple crops to several international agricultural research centres. This gave these centres a clear role as "provider of a global public good" and recognition of their importance in protecting genetic diversity as a basis for future developments.

A similar observation can be made with regard to GEO. This collaboration scheme is a direct response to calls at the World Summit on Sustainable Development (Johannesburg, 2002) and the G8 Evian Summit (2002) for strengthened international co-operation and co-ordination on global observations of the environment. It received and still receives high-level political support, through steering meetings at ministerial level.

When the need for international STI collaboration cannot be derived from global conventions or agreements and from declared political will at the top, a strict demand-led approach seems most promising to ensure that participants clearly see the relevance and invest the required resources for a successful collaboration driven from the bottom up. This is also an important element of success in international collaborations initiated through declared political will.

Lessons:

- A strong mandate helps to support commitment and ownership and thus enhances possibilities for the success of international collaboration.
- Where international STI collaboration cannot be derived from high-level political will to address global challenges in a collaborative or collective manner, demand-driven approaches seem most promising.

Aligning national and international STI programmes

It is important to link the content of international STI collaborations with agenda and priority setting at the national level in order to ensure support (financial, political and otherwise). The quality of representation that countries delegate to an international collaboration is important. The case studies demonstrate that if international collaboration is linked to national-level priorities, national representatives are more dedicated as they have the necessary resources (work time, travel budgets, staff, and other resources) to commit themselves fully to the international collaboration.

Several of the case studies – International Energy Agency (IEA) implementing agreements (IAs); Inter-American Institute for Global Change Research (IAI); Joint Programming Initiatives (JPI); and Global Earth Observation (GEO) – demonstrate this. In

the case of IAI, high-quality representatives are defined as "sufficiently empowered by their respective governments to make or influence resource commitments" (see Chapter 6), have strong links to national scientific organisations, and are able to link the IAI to other international arrangements and initiatives. In IEA implementing agreements (IAs, Chapter 7), interviewees repeatedly stressed that linking the work of the IA to national agenda and priority setting directly affected the quality of representation among IA members and the quality of the collaboration.

This indicates that the effectiveness and efficiency of international STI co-operation to address global challenges can be enhanced if the programmes are aligned with national research priorities. This observation is in line with one conclusion in the report of the Royal Society, *Knowledge, Networks and Nations*, that "International activities and collaboration should be embedded in national science and innovation strategies." (Royal Society, 2011, p. 105)

However, while the linking of national and multinational research programmes reflects current priority setting in most countries, it is not free from contradictions and conflicting interests. Excessive stress on the national basis of funding might create a serious imbalance in the agenda and priority setting of international STI efforts. Some global challenges may affect poorer countries with less advanced STI capacities disproportionally, but such challenges might have low priority if international programming is more or less directly derived from the national agendas of research-strong countries. To a certain extent, the problem of neglected diseases had its roots in such imbalances until international organisations and charities pushed them onto the global health research agenda. Therefore, aligning international agendas with national R&D agendas should be seen as a means to increase, in the short run, ownership of international R&D co-operation by key international funders and performers of STI in order to achieve a solid base of support even in times of economic turmoil and budget cuts. In the long run, however, addressing global challenges should be driven by a logic based on scientifically grounded and neutral assessment of their priority and urgency.

Lessons:

- The effectiveness and efficiency of international STI co-operation to address global challenges can be enhanced if the programmes are aligned with national research priorities. This helps to establish legitimacy and networks of support while fostering a link to holders of the purse strings and decision makers.
- While linking international programming to agenda and priority setting at the national level may be vital to success in the short run, it is not sufficient in the long run. Indeed, addressing global challenges may run counter to or – more likely – may have to be conceptualised independently of national research agendas.
- Achieving legitimacy for policy makers and ownership in the research communities of international STI collaboration will require targeted measures to raise public awareness of the chains that link investment in international STI collaboration to mitigation of current hazards and prevention of future hazards and distress.
- International co-operation generally leads to higher citation impact and the resulting visibility of domestic research efforts can be used more offensively to enhance the willingness of research policy makers and executing agencies to fund collaborative international STI efforts.

Priority setting: Broad range of actors vs. lean processes, bottom-up vs. top-down governance

While the inclusion of a broad number of actors may be instrumental in the effort to address global challenges, a broad approach to international research partnerships can also have its drawbacks, as it may prolong processes and make it difficult to reach consensus. Limiting inclusion may promote more efficient bureaucratic processes, but may also exclude some or many stakeholders, thereby limiting inputs and reducing buy-in and support. In terms of governance structures, some of the case studies demonstrate that it is useful to develop a structure that allows for both the independence of research programmes (*i.e.* largely "bottom-up") and a "targeted" decision-making process among certain stakeholders (*i.e.* largely "top-down"). Such an approach helps to reduce bargaining costs and the costs of satisfying possible veto holders and gatekeepers.

Different aspects of international collaboration may require different approaches. As one example, the case study on the Bill and Melinda Gates Foundation notes two of its major activities: creating impact based on STI, and engaging other actors through advocacy. Each of these activities requires different approaches from the perspective of inclusiveness. The former may benefit from a broadly inclusive process which brings in a diverse set of actors and activities, while the latter may achieve inclusiveness through a quantitatively more restricted but more high-level representation.

In the case of GEO, broad inclusion is congruent with the priorities of GEO members and participating organisations, and ensures buy-in. However, drawbacks are observed in the formation of priorities. The inclusive process identifies a large number of priorities and it is difficult to ascertain the most effective focal points. As a result, decisions are made from the perspective of major donors, rather than by GEO. So, while the overall process may be inclusive, it eventually creates problems, as truly research-informed priorities are not identified at the outset. The funding structure has also negatively affected priorities related to developing country needs. Although GEO has, through its work plan, addressed some developing country priorities, the articulation of priorities tends to be dominated by developed countries, due to the maturity and strengths of their systems.

A potential counterweight to such difficulties is a clear identification of roles and responsibilities. This makes it possible to include a large number of actors, but only on topics that are germane to their expertise, background or interests. This can foster an efficient governance process, as noted by the IAI, among others. Another approach consists of including stakeholders in an overall input process, but then delegating decision making to a select group to reduce transaction costs and the time required. In the case of CGIAR, the complexity of a large and comprehensive partnership, comprised of research centres, consortiums and diverse stakeholders, can make it difficult to reach global agreement on priorities. In recognition of this, while the process of priority setting is open and consultative, decisions eventually rely on the Consortium Board and the Fund Council.

Similarly, the Clean Coal Centre (CCC) IA has managed to ensure both inclusion and lean decision-making processes in its agenda and priority setting. While it asks a broad and diverse group of stakeholders to submit proposals for the work agenda of the coming year (a process that supports buy-in and inclusion), it delegates responsibility for the selection process, which goes through several rounds. The selection committee is formed of progressively smaller groups of people, thereby lowering transaction costs and fostering a more efficient decision-making process.

Directed decision-making processes need not eschew accountability. In IEA IAs delegation of decision making is balanced by accountability within the IA. IAs are independent from the IEA Secretariat and make their own decisions, but their effectiveness and outcomes are regularly reviewed by the relevant working party and the IEA Committee on Energy Research and Technology. Within individual IAs, work programmes and decision making are delegated to specific projects (or "tasks", see Chapter 7), which are independent from the larger IA, save for the necessary progress reports and other accountability measures.

Broad-based stakeholder participation *versus* efficient decision making is not the only challenge arising in agenda and priority setting. The case studies also exhibit more bottom-up or more top-down processes. Bottom-up approaches can help to ensure programmes that are demand-driven from a grassroots or micro level, while top-down approaches ensure that programmes are embedded in the larger picture of global challenges (macro perspective) with high-level political support at an early stage of an initiative. Both have benefits and drawbacks. JPIs take a primarily bottom-up approach (though they are partly guided by non-binding recommendations from the European Commission). This approach has allowed for freedom and diversity in the identification of research themes and in the formation of the institutional framework.

In GEO, a combination approach has been employed, with strategic targets derived through consultation with members, participating organisations and experts. These targets, in nine societal benefit areas, reflect the consensus of stakeholders. At the same time, decisions are made from a top-down perspective, by the Executive Committee. As a result, the process includes a bottom-up approach through horizontal consultation with stakeholders and a top-down approach through decisions taken by a designated governing body (Executive Committee).

In the case of IEA IAs, all Executive Committee members must approve the formation of a directed work programme. This helps to prevent the pursuit of programmes of work that do not provide value to all IA participants.

One of the major challenges for the institutional governance of international research co-operation is to channel the different interests of the decision makers involved. In the case of intergovernmental structures this entails consolidating the different interests of stakeholders so that the global challenge can still be effectively addressed. Some institutions try to resolve this by developing a flexible approach that allows members to organise specific work programmes (for example, IEA IAs). In this way, frameworks are created within the larger institution to address a particular programme of work, perhaps with some degree of autonomy. This type of institutional framework provides for separation of tasks and allows members to channel financial and/or in-kind input in a more targeted way to their specific area of interest.

Lessons:

- Including a broad range of stakeholders and participants in agenda and priority setting is important to achieve a larger and more detailed picture of the global challenge at hand and ensure buy-in by as many actors as possible. However, suitable governance mechanisms have to ensure that inclusion does not lead to an inefficient agenda- and priority-setting process.

- In order to achieve both an efficient agenda- and priority-setting process and inclusion, decision making may be directed to relevant stakeholders or bodies of oversight. This helps to reduce transaction costs, while maintaining transparency of the decision-making process.
- A combination of bottom-up and top-down approaches to governance may help to ensure an intelligent agenda- and priority-setting process that reaps the benefit of both approaches.

Formal versus informal or "best effort" arrangements

Collaborative initiatives may adopt formal or informal processes (or something in between). Both have drawbacks and benefits. The former may allow for clearer delegation of roles and responsibilities, and more clearly defined timelines and agendas. However, formal structures are only valuable so long as participants respect the rules and processes. Interviewees frequently noted that informal processes are beneficial for long-term collaboration and best-faith efforts. They may also, as JPI for example has found, allow for swifter adaptation to unforeseeable circumstances and lower entrance barriers. At the same time, a low level of formalisation may widen the scope for national interests to influence the JPI process.

A key aspect of the governance of GEO is its voluntary and informal structure. GEO has no legally binding documents. It is based on the premise of common benefit and a shared understanding of the need for contributions by all GEO members. As in JPI, this informal structure allows for quick response mechanisms. Members have noted that the voluntary nature of GEO is both its greatest strength and potentially its greatest weakness. One of the major drawbacks is that only a few GEO members and participating organisations make contributions; this reduces GEO's capacity to meet the needs of its stakeholders. This absence of a legally binding mechanism may also create challenges at the country level, as decisions are taken by consensus and are not binding upon GEO members. As a result, a GEO member may desire a certain action, but be prevented from carrying it out because of local restrictions. However, such members may still be able to provide support to other GEO members' efforts, perhaps in the hope that a successful endeavour by another member would give the activity political support in the member's country.

Other international collaborations have found the challenges of informal structures to be a reason to move to a formal structure. As an example, the Climate Technology Initiative (CTI) began as an in-kind initiative. Over time, this arrangement suffered from unpredictable donations. As a result, the CTI decided to adopt the IEA Implementing Agreement Framework to govern its collaboration more formally. Thus, modes of governance may evolve over time to respond to the changing needs of international collaboration.

Lessons:

- Informal governance has been shown in the case studies to generate solid support. Such governance also enables swifter response mechanisms.
- Informal governance may also involve a lack of predictability, which can create significant challenges for long-term and goal-oriented international collaboration.

- Modes of governance may evolve and be adapted over time, with informal governance ensuring ownership and motivation, and formal governance guaranteeing predictability and long-term impact.

Developing responsive agenda- and priority-setting mechanisms

A challenge noted by some case studies (for example, IEA implementing agreements and CGIAR) is that of balancing the need to be responsive to short-term needs while working towards long-term goals. This can be problematic because in order to address a specific short-term goal, resources may be re-directed from the long-term goal, making the latter's achievement more difficult. Ensuring a balance between these two aspects is vital for international collaboration in order to adapt to the evolving nature of global challenges and to reach long-term goals.

To this end, international collaboration should seek to develop both agenda- and priority-setting and funding and spending mechanisms that can be swiftly adapted in light of emerging issues in the landscape of global challenges. Examples of how this balance is achieved (*e.g.* the Bioenergy Implementing Agreement, see Chapter 7) include discussion of emerging challenges at each meeting and a "living" strategic plan with a governance mechanism that allows for adaptability. In short, developing resources (time, money, and so on) to address short-term goals can reduce the need to draw on resources for long-term goals and thereby avoid the disruption of long-term planning while still realising near-term adaptability.

Lesson:

- It is important to develop response mechanisms to respond to short-term needs without sacrificing long-term goals.

Funding and spending arrangements

STI to address global challenges is largely embedded in international research efforts, which are mainly driven by nation states. By far the largest amount of public spending for international R&D[1] is programmed, financed, monitored and evaluated at the national level, with limited collaboration or co-ordination by countries (European Commission, 2008).

Countries and world regions still mainly seek to become or remain economically competitive in a globalising economy. As a result, the scale-up of research to address global challenges stands in a complex relationship with STI for national or regional purposes.[2] In some of the case studies, collaboration depends upon national budgeting and in others (notably the Bill and Melinda Gates Foundation) it does not. In short, the organisations analysed have very different funding mechanisms and challenges as regards resource mobilisation.

Funding stability and a variety of funding opportunities are both important

Policy makers are clearly reluctant to invest significant resources in international R&D, and they face legitimacy issues and concerns about transaction costs and risks. As a first step they might scale up funding for the international mobility of researchers. By linking existing national research projects they might also broaden the scope for bottom-up international collaboration, induce learning processes that can reduce transaction costs and risks, and thus build ownership for larger funding of co-operative undertakings.

Another effective way to achieve results with a minimum of new funds is to convince existing funders with significant available funds to orient their calls or include in their calls the goals of the international governance institution. For instance, strategic targets of GEO/GEOSS have become the subject of recent calls of the European Union's FP7.

As the case studies have shown, core funding for international and collaborative STI endeavours can be quite small and based on voluntary contributions by some countries with additional funding for extra-budgetary activities from existing international organisations, funding mechanisms and/or national governments (GEO, IAI). Common funding also involves in-kind contributions, whereby countries finance national experts that work at the agency's headquarters or conduct R&D (GEO, IEA IAs). Private charities play an increasing role in research funding, particularly in health research (the most prominent example is the Bill and Melinda Gates Foundation, see Chapter 3).

Funding for specific projects rather than more generic funding to support the work of international organisations can create management challenges. In the case of CGIAR, funds directed towards specific projects accounted for two-thirds of total funding over the last decade. This led to a form of direct management of the activities of the centres by the members (mainly government agencies) and to a crisis that was reinforced by free riding and difficulties due to late announcement of annual contributions.

The crisis was both financial and managerial, as the centres were dependent on a "jigsaw" of special projects and found it difficult to make long-term plans and respect their strategic priorities. It also increased transaction costs, given the reporting, monitoring and evaluation processes required for each project by each contributing donor. In response to these challenges, CGIAR harmonised its funding scheme, requiring funders to: provide adequate and predictable funding, collaborate with one another, respond to Consortium requests to address over- and under-funding, and seek to refrain from providing funding outside the common operational framework (see Chapter 2).

Furthermore, CGIAR recognised that annual funding schemes do not always allow for effective research planning. However, donor contributions are made to CGIAR on an annual basis. Therefore, the centres have asked donors for multi-annual commitments so as to plan multi-year research programmes, but as only a few donors have done so, challenges remain in terms of funding predictability and the planning of long-term research projects.

Other CGIAR funding reforms give donors several options: they may contribute to the CGIAR programme portfolio in its entirety, to specific programmes, or to one or several centres. This allows donors to fund according to their preferences. At the same time, CGIAR has developed a multi-donor trust fund (the CGIAR Fund) for multi-year support of CGIAR research.

Other initiatives have also seen the value of establishing multiple funds, including the IAI and the IEA IAs. The IAI uses specific funds to develop a scientific synthesis of the projects of the programme and interactions among stakeholders. IEA IAs have a number of funding tools to provide both adaptability and stability. For example, in the Bioenergy IA, 10% of the task (project) funds are set aside to create a "strategic fund" that may be directed to needs arising for the Executive Committee. In the Clean Coal Centre IA, stability is provided through a one-time fee that must be submitted by all members (equal to 50% of the annual fee). The funds from this one-off payment can be used to offset late submissions of IA subscription payments, which can create problems for the co-ordination of research. The IAI has witnessed challenges resulting from late contributions to the core budget, which have reduced its dynamism.

Lessons:

- As policy makers remain reluctant to invest large amounts of money in international collaboration, funding of international mobility and similar early-stage funding may help to link ongoing research programmes and create the basis for more significant funding in the future.
- Another effective way to achieve results with a minimum of new funds is to convince existing funders to orient their calls or to include in their calls the goals of the international governance institution.
- Funding of specific projects as opposed to core institutional funding can create difficulties for the co-ordination of research and can increase transaction costs. Harmonisation of funding encourages stability.
- Annual donor contributions can make it difficult to co-ordinate multi-year research projects. If multi-annual funding by donors is not possible, funds may be created within agencies to provide multi-year funding and thus ensure stability.
- The late submission of funds negatively affects co-operation. To offset this potential hazard, a fund to provide a backstop in the case of late submission can be established.
- A dedicated fund that may be drawn upon to address arising needs provides flexibility and helps to ensure responsiveness to emerging topics without distracting from long-term plans.

Knowledge sharing and intellectual property

International co-operation in STI to address global challenges raises particularly difficult questions regarding the protection of the data, information and knowledge that result. On the one hand, vital key actors, *e.g.* from the private sector, will only invest financial and human resources and take risks of project failure if they can expect a reasonable return in the case of success. On the other hand, swift diffusion of new products and processes (clean energy technologies, drugs, enriched food) is crucial to have a significant impact on global challenges. Diffusion may be hampered if prices for innovations are too high and there are no funding mechanisms to make them broadly available.

Intellectual property rights (IPR) have an important role and influence and shape the nature of the collaboration, the agenda and its success. The success of international collaborations to address global challenges will depend upon efficient IPR frameworks that take account of the different interests of stakeholders. Innovative ways to deal with the questions of access to knowledge and intellectual property (IP) in STI to address global challenges are needed (see the example of patent pools in Chapter 9, Box 9.1).

Given the complexity of IPR issues, flexibility may be helpful in IPR regimes. In the Bioenergy IA, each participant and operating agent is responsible for identifying which information is proprietary and ensuring it is appropriately indicated. The task operating agent is in charge of deciding IP issues and informing the Executive Committee. Each participant holds the rights to its own work. As a result the IP guidelines are well-tailored to the needs of the specific task and very few problems arise.

Agreement on data sharing principles is notoriously difficult, given the plethora of national policies and laws. By agreeing on an open data policy at its establishment, GEO members and participating organisations were able to define practical mechanisms, such as the GEO-DATA-CORE, to respect the constraints under which each member or participating organisation operated.

As the International Arabidopsis Genome Project (Annex B) demonstrates, when the public sector funds research it can play a vital role by establishing policies that encourage timely data sharing, by requiring grantees to develop a data management plan acceptable to the scientific community as part of their research proposal, and by helping researchers identify appropriate repositories for the research results.

The Gates Foundation also endeavours to achieve the widest possible distribution and dissemination of scientific and technological advances and works towards IP arrangements that contribute to this goal. The Foundation makes no claim on IPR, and while it is not opposed to profiting from research results, it believes this should occur as part of the desired impact as well. The example provided in Chapter 2, for instance, is that drugs are sold essentially at cost in developing countries, but at market prices in developed countries. In short, the Foundation has a flexible IPR policy, but one that is based on the principle of global access. Each grantee must present an IP management plan, which is discussed with the technology transfer office or a lawyer, which negotiates with the grantee.

The closer a new technology is to market deployment, the more challenging IPR issues become (Evans, 2008, p. 3; Tirpak, 2009, p. 13). A US Department of Energy study noted that IEA IAs play particularly important roles for projects that are "less likely to yield proprietary intellectual property" (Evans, 2008, p. 3). However, approaches tailored to the specific needs of the collaboration that allow inventors/innovators to realise gains while still sharing results are also possible. For example, while the International Atomic Energy Agency (IAEA) owns IPRs stemming from collaborations, collaborators are free to use the results.

IPR issues are especially critical for global health concerns, as the investments and lead time needed to develop a new drug or vaccine can be very high. Yet, making at least essential medicines[3] available independently of people's purchasing power is a vital ethical concern. Funders and charities have become active in this field, and formats such as the advanced market mechanism (see Chapter 3 and specifically Box 3.1) may mobilise market forces if very significant public or charitable funding is available.

In the case of the Global Carbon Capture and Storage (CCS) Institute, (Annex A) intellectual property issues have played an important role since the early planning stage. The solution found with assistance of an international consulting group can be summarised as protecting the rights of IP holders related to the Institute, with endeavours to make IP created through the Institute's activities widely accessible to members, while collecting, packaging and sharing non-proprietary information related to CCS.

Lessons:

- The relevance of IP issues varies depending on the type of global challenge, the distance or proximity to market release, and the combination of public and private actors involved. This prohibits any "one size fits all" solution. Rather, tailored approaches need to consider research needs as well as the subsequent implementation.
- Inventors and innovators may realise gains while still sharing results. Governance approaches that encourage sharing help to diffuse research findings and build a common knowledge base.
- With regard to global health, innovative models are being implemented which mobilise the innovative power of private business, while ensuring rapid deployment of new solutions. These models should be analysed to determine their suitability in other fields.

Putting STI into practice

One of the key characteristics of global challenges is their urgency. The conversion of the output of international STI co-operation into innovative solutions on a large scale is crucial in order to reduce environmental pressures and alleviate hardships due to insufficient access to food, epidemic diseases, etc. This conversion of research into new practices occurs through evidence-based policy making, changes in societal practice and/or the diffusion of new products and processes in the business sector. Each of these modes requires specific translation mechanisms.

The importance of outreach both within and outside of the scientific community: broadening the actor constellations in international co-operation

Bridging research and policy making and/or societal practices is difficult, as policy processes are complex and rarely linear or logical (Young and Mendizabal, 2009). Success in transferring knowledge to policy makers and/or the broader public largely depends on the institutional arrangement of the co-operation mechanism and the type of actors involved. Where new knowledge is mainly or exclusively generated through scientific research, application and diffusion of new solutions may be hampered by the lack of a link to societal and economic practice. Planning of STI undertakings has to include strategies for the transfer of knowledge to policy makers and civil society stakeholders. Therefore, international collaborations should include in their agenda- and priority-setting plans the need to communicate their findings to stakeholder groups and, where appropriate, engage them in their research. More generally, efforts are needed to raise societies' awareness and acceptance of science- and technology-driven solutions that may imply the need to change living styles and societal habits.

Moving from research to political, societal or business practice requires a variety of settings and actors from the scientific community (national universities and laboratories, etc.), policy makers (at both decision-making and operational levels), funding agencies, the private sector, civil society organisations and even individuals. It should ideally be a dynamic process, occurring at several points in the research phase: before the start of a research programme to ensure that the research agenda corresponds to the knowledge

needed, during the research programme to encourage an active feedback process and to adjust the framework if necessary, and after the research is completed. The last point is particularly important for the diffusion of results and findings, and to demonstrate value to funders.

To ensure that policy making is adequately informed by research, policy makers must be aware of the relevance of STI and open to advice from other actors. Such openness cannot be taken for granted anywhere, but may be less widespread in some world regions.[4] For example, as awareness of the IAI among the policy community in Latin America is relatively low, and this has likely hindered the translation of research into policy-relevant discourse and action. The IAI has begun to address this gap with new activities, such as joint policy-science training seminars and policy briefs aimed specifically at decision makers. The IAI's efforts to link natural and social sciences with decision makers are also critical to these endeavours.

One problem mentioned in the case studies is the fact that the skills of a good policy advisor are not necessarily among the skills of an excellent researcher nor are they a necessary part of the training of future researchers. Johnson and Mendizabal (2009, p. 2) argue that in order to influence policy a good "policy entrepreneur" must be able to understand the relevant political economy, to present research results in terms of simple and compelling stories, and to network well with all stakeholders. Such a policy entrepreneur must also be able to use these skills simultaneously and in a bi-directional (*i.e.* policy-research and research-policy) manner throughout the research process. Similarly, researchers in multidisciplinary teams must work with researchers with different, complementary skills. In some of the initiatives analysed, different sections or departments of an organisation help to assemble the various skills required. At the IAEA, the Technical Department mainly interacts with knowledge users, complementing the work of departments in charge of the development of technical knowledge and applications.

As the CGIAR demonstrates, impact evaluations are essential in order to shape and refine work programmes to achieve the desired results. Plans of action must be dynamic, and evaluations are required to facilitate adaptation to changing circumstances and to achieve the desired goal most efficiently.

For many global challenges, the private sector can and should play an important role, as the business sector is generally better equipped than public actors to bring research outputs swiftly to commercial and societal application. The private sector is also an important source of STI funding. Most of the seven organisations studied are mainly or exclusively driven by public actors. An exception is the Bill and Melinda Gates Foundation, a privately owned and governed body; however, as a non-profit charity it addresses public goods.

The IEA involves industry and private entities in its IAs as an important way to accelerate knowledge sharing and to transmit to the research initiatives the needs of industry and in some cases those of end users. GEO has not yet formally defined its relationship and engagement with the private sector. However, it is currently working to reach a clear definition. This is particularly important as the private sector is increasingly a provider of Earth observations infrastructure, data and value-added products and services. It is also becoming, to a greater extent, an end user of Earth observations.

Lessons:

- International STI co-operation to address global challenges becomes operative when it leads to an efficient roll-out of innovative solutions in the business sector and society or to better policy making, informed by research.
- Evidence-based policy making must take account of the fact that researchers and policy makers are part of different environments, with different incentives, time horizons, languages, etc. Communication tools must be shaped with this in mind (*e.g.* policy briefs). Bringing representatives from both communities together at different points of the STI cycle can improve interaction between the two spheres.
- Science- and technology-based solutions to global challenges that may require adapting societal practices and habits have to be addressed by policy makers in order to ensure awareness and acceptance and a swift transition from research to practice.
- Introducing evaluations to assess the implementation of research results will support efforts to consider outcomes and impact from the beginning.
- Industry involvement is important for putting research into practice and communicating market needs. As in the case of science-policy interaction, modes of co-operation between researchers and representatives of the private sector have to consider their different interests, incentives, expectations, risk perceptions, etc. Here too, an iterative interaction process can facilitate mutual adaptation.

Capacity building for research and innovation

Most of the organisations examined in this volume do not consider capacity building and technology transfer an aspect of their mission. They see as their mission to conduct or facilitate co-operation on equal terms; this does not include helping to improve STI capacities of partners with lower R&D capabilities. Even so, implicit capacity building and technology transfer may occur if partners with less advanced R&D capacities participate in co-operative projects and carry out tasks in meetings and other types of exchanges, both in-person and virtually ("learning by doing", "learning by interacting"). However, these ways of building scientific capacities only occur if co-operation is on equal terms.

Nonetheless, some organisations explicitly make capacity building and technology transfer part of their mission. For instance, the CGIAR invests about 20% of its resources in capacity building and technology transfer, particularly by strengthening national agricultural research systems. Other examples are the Climate Technology Initiative or the Energy Technology Data Exchange under the IEA Implementing Agreement Framework which explicitly focus on technology and knowledge transfer to developing countries.[5]

An issue relative to capacity building noted in the CGIAR case study was the effort to avoid duplication; in particular, research done at the international level should not "mirror" activities done at the national level. While the avoidance of duplication is a worthwhile pursuit in the short term, there remains the challenge of building capacity in participant countries and organisations in the long term. If capacity building does not take place by "doing" it needs to do so in other ways. Therefore, North-South and South-South capacity building and knowledge transfer should be an important part of international research collaboration. In the case of the IAEA and other organisations, links with UN organisations such as the World Health Organization (WHO) and the Food and Agriculture Organization (FAO) may be useful in this regard.

Reconciling STI and development agendas

In addressing global challenges, the involvement of developing countries is of special importance: "As the issues are global, involving less developed countries with few financial means to engage in research and technology is essential for its success (and for tackling the impacts on those particular countries)." (Boekholt *et al.*, 2009, p. 15) Yet, international research co-operation has traditionally occurred either among the scientifically and technologically most advanced countries in the North or through rather limited North-South co-operation projects.[6] Patterns of scientific collaboration are also influenced by language and historical links among different countries and world regions.

Some of the case studies in this volume indicate that international undertakings can help to dissolve these traditional patterns of co-operation and reshuffle partner structures, thereby enhancing the potential for a creative recombination of production factors, including specific knowledge and capabilities, in different local environments. This also includes South-South co-operation in STI, traditionally a weak field of international research collaboration.

The most obvious case in this sense is IAI, conceptualised as a regional mode of co-operation, with a strong focus (including the location of headquarters) in the developing and emerging countries of Latin America. Prior to IAI's establishment, collaboration between research institutions and universities in Latin America was underdeveloped. The IAI governance and management structure supported regional co-operation and enabled the creation of international and multidisciplinary networks among leading scientists in the Americas. The resulting scientific exchanges have contributed significantly to the region's capacity to engage in research on global change phenomena, and there are possibilities for further linking IAI to other international organisations dealing with global change.

The IAEA has also fostered regional networks. One example is the regional and co-operative agreements in Africa, the Middle East, Latin America and the Caribbean, and Asia and the Pacific. These regional networks also serve an important function in South-South co-operation and knowledge exchange.

By bringing together a wide array of international researchers that represent both the public and private sector, IEA IAs have created multiple networks simply through their establishment. The inclusion of policy makers in IA Executive Committees further diversifies this interaction (and helps to create research-policy links). Networking also occurs with the IEA Secretariat, including working groups, expert groups, and other entities. Furthermore, IAs with complementary work programmes are linked through a number of IEA structures where relevant. These interlinked networks make knowledge sharing more dynamic and effective.

CGIAR has been successful in involving developing countries in its work, partly because of the absence of a financial threshold to be a member and/or contributor. Furthermore, seats in the Fund Council are distributed fairly among North and South countries and donor contributors. At the IAEA, the combination of promoting collaborative research and technical co-operation programmes is especially promising in terms of generating new knowledge and – at the same time – ensuring its application in a large variety of countries.

It can be challenging, however, to meet advanced science and effective development criteria simultaneously. This is recognised in some of the organisations studied, notably the IEA IAs. As these are primarily burden- and benefit-sharing agreements, it is rather difficult to include developing countries in the work programme. This may be easier when the barrier to joining is an annual fee and harder when it requires significant national infrastructure for conducting advanced research.

In order to utilise existing knowledge and to link to research initiatives in the South, CGIAR has included emerging research centres as partners along with advanced research institutes of the North. In this way, triangular collaborations of less developed, emerging and industrialised countries shape the international research system of the future through three-way co-operation. CGIAR also catalyses research and innovation by leveraging the resources and competencies of other actors through collaboration, brokerage and networking; facilitating spillover and scaling-up of technologies; funding mobilisation; and the establishment of regional and global technical facilities.

Through the GEONETCAST initiative, GEO is working to address differences in capacity. This low-cost data dissemination and delivery system was established to distribute data in low bandwidth environments. GEO has also developed GEONETCAB, which aims to promote capacity-building activities in support of GEO. It focuses partly on brokering support for Earth observation capacity-building projects and activities in developing countries; it addresses all GEO societal benefit areas but places special emphasis on climate monitoring. GEONETCAB identifies capacity-building needs and potential resource providers for capacity-building activities. It develops mechanisms to facilitate co-operation among stakeholders and resource providers and access to a global network of expertise for education and training in Earth observation. In its work on capacity building, GEO does not treat this as a niche that concerns developing countries, but rather as an essential component of all GEO activities.

The IAEA does not have field offices in partner countries and depends on partner organisations to conduct outreach activities. Capacity building and technology transfer are important elements of IAEA activities. Building members' capacities to work responsibly with nuclear technologies (for energy generation and beyond) has been a core element of the Agency's mission since its inception. In its work to support developing countries IAEA has realised the benefits of a bottom-up approach to governance.

Lessons:

- STI capacity is crucial for addressing global challenges through international research collaboration. Challenges such as food insecurity, climate change, environmental degradation, infectious diseases and shortage of energy supply require STI-based responses even in countries with relatively small STI capacities.
- Bridging the knowledge gap requires considerable investments in STI capacities in developing countries. Linking different initiatives can help to foster capacity building, specifically by linking international STI collaboration, and thus processes of learning by doing and learning by interacting, with development assistance, which has capacity building as a core mission.
- International collaboration can foster South-South co-operation, an important element of STI capacity building. As this mode of co-operation is rather new, it should be given higher priority in the design of multilateral and international STI endeavours.

- Treating capacity building as a "niche" element of governance relating only to developing countries is not helpful. It should be part of all governance approaches, as STI capacities also diverge in the more advanced countries and between disciplines and sectors.

10.3. Conclusion and further research perspectives

Organising international STI co-operation appropriately is not just a technical challenge. It also implies dealing with a diversity of expectations, resources, capabilities and powers of decision. Notwithstanding such differences, many actors have to be engaged in addressing global challenges and need to align their co-operative activities to meet this goal.

International co-operation can unlock important potentials of STI to deal with major concerns of humankind today. However, increased collaboration may come at the expense of efficient processes of planning, conducting and monitoring research. As complex and networked co-operation across national and cultural boundaries leads to significantly rising transaction costs and risks, the net benefit of international STI co-operation is directly related to the organisation of the phases of collaboration. These organisational methods constitute the governance of international STI co-operative endeavours. Table 10.1 represents the governance dimensions analysed throughout the work in rows. The columns identify three manifestations of these governance dimensions ("modes of governance"). In a rather stylised manner, the columns represent "poor", "improved" and "good" modes of governance. The main qualifying factor is the aptitude of governance to adapt to changing framework conditions and to the varying requirements in the life cycle of collaboration.

Considering the importance of international STI co-operation in the field of global challenges, and the need to organise it efficiently, the relative scarcity of relevant conceptual and empirical literature is striking. In many other fields (*e.g.* environment, trade, finance), international and multi-level governance has recently ranked high on the scientific and political agenda.

The complexity of the task of governance and the idiosyncrasies of individual global challenges make it clear that no set of simple "do's and don'ts" will help national and global policy makers to solve the many issues related to international STI co-operation easily. Nevertheless, the research presented in this volume offers some valuable orientations although further research is clearly needed.

Table 10.1. Governance modes illustrated in the case studies

Governance dimension	Governance mode (sub-optimal)	Governance mode (improved, but not adaptive or responsive)	Governance mode (adaptive and responsive)
Priority setting *Stakeholder involvement*	A limited number of stakeholders are involved, reducing input, buy-in and transparency	A broad range of actors is included in the decision-making process, but transaction costs are increased	A "directed" decision-making process minimises transaction costs by closely defining the decision-making "jurisdiction" of stakeholders
Flexibility in priority setting	Flexibility to adjust priorities to address arising needs does not exist	Flexibility to adjust priorities to address short-term needs is provided for, but without balancing the need to provide for long-term priorities	Governance mechanisms allow for flexibility to address short-term needs without sacrificing resources for long-term goals
Funding and spending *Nature of contributions*	Funding and spending requirements and commitments are not clearly defined	Funding and spending requirements and commitments are clearly defined, but do not provide for contingencies	Funding and spending requirements and commitments are clearly defined, and include contingency funding for late submission of payment, and balance project financing with longer-term general funds, *inter alia* to support continuity and stability
Flexibility in funding and spending mechanisms	Funding and spending mechanisms do not allow for adjustment to address unpredicted needs	Funding and spending mechanisms allow for flexibility and re-adjustment in order to address arising needs but without balancing the need to maintain resources for long-term goals	Funding and spending mechanisms allow for the realisation of long-term goals while responding to short-term needs (*i.e.* a strategic fund that provides for short-term funding while not drawing on long-term funding)
Knowledge sharing and intellectual property	IP provisions are undefined	IP provisions are defined for the duration of the project, but do not allow for adjustment during the project life cycle	Defined IP provisions allow for adaptation during the project life cycle – this includes IP provisions adapted to the life cycle of the collaboration
Putting STI into practice *Outreach to end-users and broader society*	Research is conducted without a plan or the resources for sharing results	Research is conducted with a plan and the resources to share results, but fails to engage in two-way communication with end-users throughout the project life cycle	Research is conducted to share research agendas, activities and results throughout the project life cycle while maintaining a two-way exchange process with end-users; awareness raising and acceptance building are essential elements of the outreach activities
Capacity building for research and innovation *Avoiding duplication*	Research is conducted without building capacity in partner countries	Capacities are built up by conducting joint research, but duplicate activities, results and errors	Capacities are built up while maintaining a focus on avoiding duplication of activities, results and errors by sharing research agendas and co-ordinating efforts

The research and analysis contained in Chapter 9 are thus the basis for some first policy options that have emerged from the empirical research. They are proposed as a means of establishing initial framework conditions for effective governance. When a new mechanism for international co-operation in STI for global challenges is formed, or an existing one assessed, the case studies point to an initial "checklist" of policy options.

- *The importance of high-level co-ordination of the project.* International STI co-operation is especially likely to succeed if it can be derived from high-level political commitment to act collectively to address a particular challenge and/or achieve a certain goal. This can give researchers and their organisation a strong mandate and enhances ownership and buy-in by many governments and funders.
- *Need for a compelling reason to do the work.* Where a link to high-level political commitments cannot be made, a demand-led approach seems most promising. Co-operation should focus on fields with clear knowledge needs shared by many decentralised actors who perceive clear benefits to international co-operation when compared to acting on their own.
- *The governance structure must be a "learning system".* Governance structures should be tailored to the needs of the specific collaboration, and allow for active and responsive adaptation. Provisions, including impact evaluations to assess the efficacy of activities, should exist to change governance modes as and if required to support efficiency and effectiveness. The evolving nature of global challenges further highlights the need for structures that are adaptable in all governance dimensions. Regular evaluations are an essential tool for catalysing institutional learning.
- *System linkages are important.* Effective multi-level governance, understood as establishing and maintaining linkages between different system levels (local, regional, national, international), should be sought in order to avoid duplication and encourage transparency. Linkages should seek to include a broad and relevant range of stakeholders while maintaining an effective decision-making process. Responsibilities and decision-making should be delegated in order to reduce transaction costs while maintaining broad stakeholder involvement.
- *Outreach and knowledge flows outside the project.* Outreach from the research community to other stakeholders should be a priority. This is essential to ensure support (political, financial and otherwise) for international collaboration, to disseminate results, and to demonstrate to existing and potential participants the value of the collaboration. Outreach should occur at multiple phases: pre-research, during research, innovation and post-research. Outreach should target a wide variety of actors: voters, decision makers, the research community, the private sector and others.
- *Knowledge flows and knowledge protection.* Knowledge sharing and IP provisions should be adapted as necessary to each phase of the collaboration life cycle. This is particularly important given that IP issues tend to increase in importance as a product nears market deployment.
- *Contingency management.* Funding and spending mechanisms should contain contingency provisions. In the case of delayed payments, or the need to fund multi-annual research projects with annual funding, mechanisms are needed to provide for funding and spending stability.

- *Combining co-operation with capacity building.* With regard to global challenges, the traditionally strict separation between evenly balanced co-operation in STI (equal contributions, equal benefits) on the one hand; and capacity building on the other, should give way to a more integrated approach. For most global challenges, research contributions are needed from a wide array of countries, rather independently from their STI capacities. Capacity building is an important element of joint efforts to address these challenges, and should not be seen as a support mechanism only, or not even mainly, in the interest of the less developed country.

These options emerge from the analysis of the seven case studies on existing STI collaborations dealing with global challenges. Given this, several points should be considered. First, these are successful examples of international STI collaborations in the field of global challenges, although some are more successful than others. Second, the case studies all focus on international STI co-operation related to the interaction of human activities and the natural environment, and mostly deal with limited natural resources. In the last three to four years it has become very clear that global challenges with potentially catastrophic consequences can also arise in human-made systems, *i.e.* the global financial system. Here, as in human-nature interactions, certain elements of the system may change gradually (subprime loans in the banking system, public debt) until the point at which a further shift can lead to a catastrophic breakdown of the whole system. These purely human-made global challenges are another area for further research.

Third, all of the case studies, with the exception of the rather recent JPI and the Global Carbon Capture and Storage Institute, analyse institutional settings that were politically feasible and adopted under much less globalised conditions and with much less awareness of the global challenges than is the case today. This might have led to certain degree of path-dependent thinking in the policy options proposed above. Incremental improvements in governance patterns may not seem to be an adequate response to the magnitude of problems mankind faces today. More radical alternatives might also be available through new trends in the way knowledge is sourced.

The scale and urgency of the need to mobilise STI to address global challenges and the new modes of generating, sharing and applying knowledge mean that more radical means of international research governance than those described in this chapter may need to be found. This volume has proposed a starting point based on a number of successful efforts but suggests the need for "out of the box" thinking and further work in order to meet emerging challenges.

Notes

1. In many countries, the private sector spends the most for STI and tends to be rather cautious about investing financial resources for strategic R&D beyond the firm's home country (*e.g.* Belitz, 2010).
2. The tensions are at least partially reflected in official documents. For instance, in February 2005 the European Commission refocused the Lisbon Agenda, which initially focused exclusively on Europe's competitiveness, on actions that "promote growth and jobs in a manner that is fully consistent with the objective of sustainable development".
3. See 't Hoen (2010), p. 129ff. on the concept of essential medicines.
4. For instance, in the United Kingdom, evidence-based policy making has gained momentum since the first Labour government of 1997, which declared evidence-based policy a core element of its commitment to modernising government (Sanderson, 2002, p. 4).
5. See Box 9.2 on the European and Developing Countries Clinical Trials Partnership (EDCTP).
6. A recent study indicated that only 3% of Southern African Development Community (SADC) papers during 2005-08 were jointly authored by researchers from two or more SADC countries, and only 5% of SADC papers were jointly authored with researchers from African countries outside the SADC. In contrast, 47% of SADC papers were co-authored with scientists from high-income countries (Boshoff, 2010).

References

Belitz, H. (2010), "Internationalisierung von Forschung und Entwicklung in multinationalen Unternehmen", *Studien zum deutschen Innovationssystem*, Vol. 6-2010, Berlin.

Boekholt, P., J. Elder, P. Cunningham and K. Flanagan, (2009), "Drivers of International Collaboration in Research", Technopolis Group Report, University of Manchester.

Boshoff, N. (2010), "South-South Research Collaboration of Countries in the Southern African Development Community (SADC)", *Scientometrics*, Vol. 84(2), pp. 481-503.

European Commission (2008), "Towards Joint Programming in Research: Working Together to Tackle Common Challenges More Effectively", Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions , COM(2008) 468 final, *http://ec.europa.eu/research/press/2008/pdf/com_2008_468_en.pdf*

Evans, Meredydd (2008), "International Energy Agency Implementing Agreements and Annexes: A Guide for Building Technologies Program Managers", Lawrence Berkeley National Laboratory.

Friedman, T. (2005), "Bush's Waterlogged Halo", *The New York Times*, 21 September.

t'Hoen, E. (2010), "The Revised Drug Strategy – Access to Essential Medicines, Intellectual Property, and the World Health Organization", in G. Krikorian and A. Kapczynski (eds.), *Access to Knowledge in the Age of Intellectual Property*, MIT Press, Boston, MA, pp. 127-140.

Krikorian, G., and A. Kapczynski, eds. (2010), *Access to Knowledge in the Age of Intellectual Property*, Zone Books, New York.

Sanderson, I. (2002), "Evaluation, Policy Learning and Evidence-Based Policy Making", *Public Administration*, Vol. 80(1), pp. 1-22.

Royal Society (2011*), Knowledge, Networks and Nations. Global Scientific Collaboration in the 21st Century*, The Royal Society, London

Tirpak, D. (2009), "Regional Strategic Partnerships for Energy Security and Climate Challenges", Paper presented at the 2009 EWC/KEEI International Conference on Fossil Fuels to Green Energy: Policy Schemes in Transition for the North Pacific.

World Bank (2011), *A New Era for Open Knowledge. Results, Connectivity, Openness*, The World Bank, Washington, DC.

World Science Forum (2011), "Declaration of the Budapest World Science Forum 2011 on a New Era of Global Science", *www.sciforum.hu/cms/upload/docs/programme/WSF_2011_Declaration_adopted.pdf.*

WSIS (World Summit on the Information Society) (2003), "Geneva Plan of Action", First Phase of the WSIS, *www.itu.int/wsis/docs/geneva/official/poa.html.*

Yang, C.J. and M. Oppenheimer (2007), "A 'Manhattan Project' for Climate Change?" in *Climatic Change*, Vol. 80, pp. 199-204.

Young, J. and E. Mendizabal (2009), "Helping Researchers Become Policy Entrepreneurs. How to Develop Engagement Strategies for Evidence-Based Policy Making", Overseas Development Institute, Briefing Paper 53.