Chapter 9

Improving science, technology and innovation governance to meet global challenges

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This chapter reviews the literature on five dimensions of international science, technology and innovation (STI) governance: i) *priority setting,* ii) *funding and spending arrangements,* iii) *intellectual property,* iv) *putting STI into practice and* v) *capacity building. It is supported by the case studies presented in the preceding chapters. Finally, it presents preliminary steps towards governance options and some paths for further research.*

9.1. Introduction

This chapter considers how governance mechanisms to facilitate international co-operation in science, technology and innovation (STI) can help to respond to global challenges. It reviews the literature and draws on the case studies contained in this volume and on other sources to propose a set of governance options for tackling global challenges and reducing their negative social and economic impacts.

The case studies presented in Chapters 2 to 8 describe a number of projects, mechanisms and organisations established in various fields, at various times and with diverse structures to meet important global challenges. This chapter analyses the five dimensions of governance on which the case studies focus: *i)* priority setting, *ii)* funding and spending, *iii)* knowledge sharing and intellectual property, *iv)* putting STI into practice and *v)* capacity building for research and innovation. It also draws on in-depth analyses of these governance dimensions that accompanied the case studies that were prepared by the expert teams from Austria, Germany, Norway and South Africa. Its overall aim is to identify the main strengths and weaknesses in their governance in order to point to governance options to facilitate timely action for international STI co-operation to meet global challenges.

For each of the dimensions considered, the analysis reviews the literature, synthesises the salient features of governance in the case studies, and considers the challenges and governance options. The chapter concludes with a synthesis of the prominent assumptions and their implications for each dimension as a basis for sound governance.

9.2. Priority setting[1]

The literature on STI priority setting mainly focuses on national contexts, given that most STI efforts and thus priority setting have been national endeavours. A synthesis of the case studies highlights salient features of the present governance of priority setting and offers some insight into the challenges facing priority setting in the context of international STI co-operation. The various trade-offs that are needed to ensure that priority-setting processes support the delivery of the desired global public goods are discussed and the governance options outlined.

STI priority setting: Definition and main features

Priority setting can be defined as a negotiation process in which diverse actors and stakeholders seek to agree on common goals, objectives and actions. Agenda setting concerns the public discourse designed to raise awareness of specific problems and challenges. The successful tackling of global challenges implies a sustained effort to put the relevant issues on the agenda on a broad scale and on a long-term basis. It is assumed here that the identification of global challenges and their presence on the agenda is a prerequisite for priority setting.

Priority setting can be classified according to its drivers or according to its goals. Stewart (1995) defined three priority-setting models based on drivers: user-based, institutional and political. Selection of priorities is determined by users' needs, by rewards for researchers or by broader policy choices. Priority setting may also depend on thematic or structural priorities. Since STI priority setting involves various stakeholders, drivers may differ. They can target the economic efficiency of public research and public research funding management (OECD, 2010a, p. 8) and thus create tensions with the scientific community, which emphasises excellence of research results. Alternatively, they can pursue political and societal goals so that research contributes to people's welfare and social well-being, sustains internal and external security, and delivers solutions to global challenges.

Other sources of tension can appear during STI priority-setting processes: specialisation *vs.* diversification, choice of the targeted stage of the STI process, supply- *vs.* demand-led orientation, varying time horizons, uncertainty about resources and the actual state of the world. This leads to diversity and complexity in designing priorities to address global challenges (OECD, 2010a; Dalrymple, 2006).

Historically, there have been four main approaches to STI priority setting. A traditional mission-led (*i.e.* application-led) approach, a technology-oriented approach based on the identification of key technologies for civilian industrial purposes, a systems-oriented approach to enhance national innovation systems, and the more recent "new mission-led approach" for technologies to cope with new societal challenges (Gassler *et al*., 2008). The last of these combines social needs and technological input, identifies and selects priorities in a decentralised manner, involves multiple actors from different sectors, and favours the fastest path to implementation (*e.g.* incremental innovations). Governance is not confined to governmental or government-authorised actors but involves stakeholders from other areas that form policy or negotiating networks. Whereas traditional governmental policy is based on the distribution of public goods provided by the government, new modes of governance establish co-production of public goods whereby different actors (public and private) contribute to public benefits.

Finally, different phases can be identified in the priority-setting process:

- *i)* formation of priorities; and *ii)* implementation of priorities (Salo and Liesiö, 2006).
- *i)* creation of a framework; *ii)* identification and selection of priorities; and *iii)* provisioning the implementation of the chosen priorities (Mahroum *et al.*, 2005).

Priority setting does not end with the definition and establishment of topics or areas of research. Strategies for implementing the selected priorities and establishing the relevant research programmes should be considered concomitantly with the priority-selecting process. Although the priority-setting phase is distinct from the implementation phase, it is important to consider the resources and capacities (knowledge, networks and money) that are available or have to be made available to implement the chosen priorities. These estimations should be a key part of the related strategic plans.

Lessons from the case studies

Different levels of involvement and control

Most of the forms of international STI collaboration investigated feature a principal policy-making organ in which full members hold decision-making powers. This body is also responsible for decisions on research priorities and implementation strategies. When a scientific advisory board exists, it is mainly responsible for developing a scientific research agenda and has limited power. Stakeholders are sometimes involved, in more or less formalised ways, in the definition of programmes and priorities.

Forms of international STI collaboration such as the Group on Earth Observation (GEO), the Joint Programming Initiatives (JPI) or the Consultative Group on International Agricultural Research (CGIAR) try to involve a broad set of stakeholders in priority setting even though they are established and governed by governments or by government-authorised actors that dominate the decision-making bodies and process. Implementation of priorities is dependent on resources made available by members, *e.g.* by aligning national activities or by contributing to a common pot devoted to specific activities/priorities. This of course favours the implementation of priorities formulated and driven by the interests of the main contributors. In some instances this could be detrimental to priorities of common interest.

For instance, the Agriculture, Food Security and Climate Change (FACCE) JPI has applied a "variable geometry approach" which means that not all participating countries need to be involved in specific topics or tasks. This provides opportunities for flexible priority-setting arrangements. However, the principle of variable geometry is quite prone to capture by the interests of powerful and well-endowed actors. An indication of this is the low level of participation of new EU members in proposing themes for the European Commission's JPIs. Similarly, the decisions of GEO, which are the result of an open and bottom-up process involving many governmental actors, are constrained by the support received from national governments. The GEO therefore seems to face the same challenge as JPIs: a flexible approach can favour the interests of powerful and well-endowed actors or states.

Some international agencies have succeeded in counterbalancing the power of their most influential members. The International Atomic Energy Agency (IAEA) and its personnel, for instance, have developed their own strategic interests which they try to pursue along with the interests of members. STI priority setting within the IAEA is therefore conducted "top-down" but is also influenced by IAEA scientists who try to steer priorities away from the often subjective interests of member states. The IAEA also tries to overcome conflicting and diverging national interests by putting on the agenda problems that go beyond solely national interests and are of regional or global importance.

Selection of priorities: broad vs. narrow

In international STI collaborations priorities are often defined very broadly. Broad definitions of priorities ensure that all actors have a chance to recognise their specific interests and that the priorities will have broad legitimacy and support. However, the translation of priorities into specific actions or tasks is challenging as priorities can be implemented in different ways with different orientations. Strategies for and means of implementing priorities should be considered to achieve narrower and operational definitions of the selected priorities.

Challenges for international STI priority setting

One essential characteristic of contemporary global governance is its fragmentation. This means that no central authority has regulatory powers (Messner, 2003; Biermann *et al.*, 2009). Priority setting has to be organised to allow a wide range of societal groups to bring their interests, needs and knowledge to bear on the framing of the agenda and the setting of priorities (Kaul *et al.,* 1999a). However, a large number or diversity of actors and differences in the distribution of power and capacities leads to high transaction costs or even to stalemate. Indeed, broad participation of all relevant stakeholders is often seen as an obstacle to efficient governance. A trade-off seems to exist between efficiency of governance and participatory or democratic approaches with broad stakeholder involvement.

However, while there are disadvantages to broad participation there are also dangers in modes of governance that involve a small number of actors. These closed or exclusive modes of governance are very vulnerable to capture[2] and likely to act not in the public interest but in the interests of a rather small and powerful group (Mattli and Woods, 2009). For example, strong vested interests are very common in transnational STI collaboration efforts and are basically related to national STI interests. These well-established and strong national STI interests are likely to build biases into deliberative processes on international STI collaboration which need to be overcome. Involving a diversity of stakeholders and balancing the competing interests of diverse actors, countries and regions is therefore a key challenge in setting STI priorities for global collaboration and developing common overall objectives and priorities.

Providing knowledge on the causes of global challenges and on the mutual benefits of co-operation can help to reduce barriers to collaboration. Difficulties in creating a broad consensus through priority-setting processes can arise from differences in the perception of global challenges and of their urgency. Even if they are called global challenges, their causes and effects are not evenly distributed among countries and world regions (Weber, 2007). Even when the causes and effects of global challenges are generally recognised, stakeholders may still hold diverging views on approaches to solutions. One way to mitigate differences in perceptions of the issues would involve the use of the tools of "strategic policy intelligence" (SPI) to the extent possible in the priority-setting process. Quite often, lack of or asymmetrically distributed information hampers evidence-based priority setting. The use of foresight exercises and other SPI tools could facilitate common understanding and consensus building.

Fragmentation, diversity of stakeholders and vested interests also generate information asymmetries. For STI, this is especially relevant in negotiations among policy makers and stakeholders from civil society and from the scientific community, as they rely on different sources of information and have different types and depths of knowledge on the issues involved. In this context the role of scientific evidence and the involvement of experts are particularly important in deliberative processes to establish a common understanding and to reach consensus. As noted by Martin (1999, p. 51), "By changing the informational environment, [institutions] change state strategies in such a way that self-interested states find it easier to cooperate reliably with one another".

Governance options

The challenge of establishing broad stakeholder participation leads to the question of how institutional arrangements for priority setting should be designed to facilitate a balance between competing interests and yet achieve efficiency goals.

Governance scholars point out the need for mechanisms that facilitate broad participation by different stakeholders (Walk, 2007). Due process mechanisms and formal regulation of processes and procedures are a prerequisite for broad participation and inclusion of stakeholders; they also counter unequal distribution of power and resources between stakeholders (Albin, 2003).

It is not sufficient for a deliberative process to be open in principle to all relevant stakeholders. Stakeholders also need to be encouraged to participate and their participation must be actively supported by providing resources and/or information (Kaul *et al.*, 1999b). More equity and enhanced representation by weaker countries and international civil society and organisations will lead to more equitable outcomes.

A combination of bottom-up and top-down approaches reduces the risk of possible biases in priority-setting activities because more actors and interests are involved. Selected priorities should reflect existing research competencies and capacities as well as emerging societal needs and challenges (Salo and Liesiö, 2006). Supply-led and demand-informed approaches for priority setting driven by scientific communities on the one hand and society and policy on the other should not be viewed as mutually exclusive.

Although priority setting is distinct from implementation, it is very important to consider in advance what kinds of resources and capacities (knowledge, networks and funding) will be available or will have to be made available to implement the selected priorities. Priority setting should be closely linked to budgetary issues and negotiations, bearing in mind that the higher the level of resources secured beforehand, and the more equitable the priority-setting process, the more likely its outputs will be relevant to meeting the challenges faced. In short, an effective priority-setting process should:

- Include broad and active participation of relevant stakeholders and support information flows to achieve common understanding and consensus.
- Mix different approaches, such as bottom-up and top-down, supply-led and demand-informed, to avoid possible bias in the selection process.
- Be linked from the outset to budgetary and implementation issues.

9.3. Funding and spending arrangements[3]

Funding and spending are key dimensions of the governance of STI collaborations aimed at meeting global challenges. Funding refers to the way in which actors provide money for a specific STI initiative, while spending refers to the allocation of money for activities, tasks, sub-organisations, etc. The two may be interrelated in funding models in which the funding agreement contains decisions on spending, but this is not necessarily the case. Funding and spending have many intersections with other governance dimensions. For example, funding is closely related to issues of priority setting, and both may have elements relating to intellectual property rights (IPRs), capacity building and so on. A key challenge is to find ways to scale up funding while maintaining accountability, efficiency and co-ordination.

The four aspects of funding and spending discussed here are: *i)* funding models; *ii)* asymmetries and absorptive capacity; *iii)* market and system failures and incentives for private participation; and *iv)* effectiveness and accountability through monitoring and evaluation.

Funding models

Many different funding models are employed in multinational frameworks for STI collaborations.[4] Cultural, economic and political contexts matter, as do the characteristics of the collaborations themselves. Failure to appreciate, for example, the different processes involved in creating new scientific knowledge and supporting innovation is likely to be detrimental to any funding model.

A fundamental aspect of STI funding is the balance between core and project funding. Many organisations involved in international STI collaboration struggle to maintain this balance, as sufficient core funding is often difficult to obtain, while often volatile, in-kind and project contributions make long-term planning difficult. Categories such as "real common pot", "virtual common pot", "mixed mode pot" or "no common pot" (see Table 8.1 in Chapter 8 for a detailed overview of these categories) all have context-dependent advantages and drawbacks. The case studies in Chapters 2 to 8 show that voluntary, in-kind contributions may be useful for securing funds relatively quickly, but may also impede the shaping of coherent long-term strategies. It is crucial to strike a balance between mandatory core funding and allowing for more flexible in-kind and project funding.

The CGIAR has succeeded in establishing a flexible funding mechanism. Financial support for the CGIAR is harmonised through a multi-donor trust fund (the CGIAR Fund) which is intended to serve as a strategic financing facility for multi-year support of CGIAR research. Donors can decide on the use of their funds by allocating them to three "windows": the entire CGIAR programme portfolio as unrestricted funding; specific research programmes that are part of the agreed programme portfolio (programme funding); one or more CGIAR centres. Experience has shown that these three windows provide the flexibility needed to allow donors to fund single activities according to their preferences while maintaining coherence in operations through a certain level of core funding.

Asymmetries between contributors and beneficiaries and in development and absorptive capacity

STI capacities are unevenly distributed across the world, and global challenges affect different nations and regions in different ways. The differences between STI capacity and the effect of global challenges on different communities have to be taken into account when designing STI funding.

Policies of *juste retour* or "fair return" are common in intergovernmental STI activities; they ensure that national governments get a "return" on their STI investments.[5] To ensure sufficient upscaling of the STI funds needed to address global challenges, the principle of fair return must most likely be tempered. An element of "altruism" may be needed, as in the field of global health, where a number of very visible and highly influential foundations support STI activities. Such an approach, coupled with more conventional foreign aid, can be a valuable resource for STI endeavours to address global issues. Moreover, deficiencies in STI funding point to the need for new and more effective institutional frameworks for international STI collaboration.

Currently, a sizeable amount of funding is directed towards research activities in OECD countries, though indicators show that collaborative research between advanced and developing country scientists is rising (Wagner *et al.*, 2001; OECD 2011a). To tackle global challenges effectively will require local capacity and absorptive capacity building in many cases (see the section on capacity building). This may require a better allocation of resources to developing countries and the establishment of close links between STI and development policy. However, there may be tensions between capacity building and efficiency (Wagner *et al.,* 2001). Many collaborative research projects seek to address this issue. It should also be emphasised that technological fixes alone cannot deal with all of the components of global challenges; broader political and social issues may also need to be addressed (Leach and Scoones, 2006).

Market failures and incentives for private participation

STI endeavours are risky and rife with issues of non-appropriability (Arrow, 1962) and information asymmetries; they may therefore suffer from underinvestment. In addition, innovation is a complex social process and can be affected by path dependencies and lock-ins. Innovation theory stresses that innovation takes place within the context of firms, organisations, universities and legal frameworks (Metcalfe, 1995; Smith, 2000). This understanding of the innovation process opens up the possibility of policies to change institutional frameworks through education, IPR regulations, capital markets and regulated industries, which emphasise both competition and co-operation (Lundvall and Borrás, 2005). The funding and spending models represented by the JPI, the CGIAR and the Bill and Melinda Gates Foundation exemplify attempts to change the institutional context and alleviate market and system failures.

The severity of global challenges is arguably too great for the public sector to bear the cost alone.[6] The private sector needs to be engaged to a much greater extent than is currently common, perhaps especially in developing countries where the private sector supports a significantly smaller share of total R&D than in developed countries (OECD, 2009; Marr and Chancellor, 2005). For the private sector to participate in such research, it needs to expect reasonable returns on its investments. Thus issues of demand, access to markets, and legal and institutional frameworks, including IPRs, have to be looked at. It also helps to make opportunities clear to the private sector and to facilitate co-funding schemes.

Among the case studies, the Bill and Melinda Gates Foundation is arguably the organisation that has, in various ways, been the most successful in facilitating co-funding schemes and co-operation by public and private entities. One of the Foundation's prominent characteristics is its attention to public-private partnerships that are able to harvest the resources of a range of public, private and non-profit organisations. By allowing for flexibility in their projects, especially with regard to IPRs and research contracts, the Foundation has been able to make collaborative research initiatives attractive to the private sector.

Effectiveness, accountability, monitoring and evaluation

The high level of private-sector involvement needed to tackle global challenges efficiently raises issues of legitimacy that differ to some extent from those of public actors (Biermann, 2007; Biermann *et al*., 2010). Although the involvement of the private sector can be beneficial in several ways (and can provide a diversity of opinions), the increasing need for privately financed research creates concerns regarding the transfer of more rights and responsibilities to non-state actors. Policies that protect the interests of civil society are needed (Biermann *et al*., 2010; Royal Society, 2011). A balance between accountability and efficiency, as well as between input accountability (related to priorities and influences on them) and output accountability (related to efficiency) must be struck.

The link between funder and recipient can be considered in terms of a principal-agent relationship, as significant authority is delegated from political to scientific actors (Guston, 1996, 2003). Such relationships are often associated with problems of information asymmetries, moral hazard and adverse selection (Van der Meulen, 1998). Monitoring and evaluation can reduce these problems but are also associated with costs which need to be considered. Different organisations use different methods of monitoring and evaluation, including *ex post* and *ex ante* evaluation, peer review and foresight (Hansen Hanne Foss, 2009). Reporting requirements vary from annual reports to milestone project management. A fair amount of experimentation is most likely needed to find good solutions in each case.

With increased attention to accountability, efficiency and effectiveness in government-led research, monitoring has gained importance in most OECD countries. There has also been a shift from focusing on legitimising past initiatives to improving understanding and establishing better policies for the future (Kuhlmann, 2003). The learning ability of a project is a very important function of monitoring and evaluation. Large differences in monitoring and evaluation practices between countries, together with increasing concern with the link between evaluation and strategy building, offer opportunities for policy learning. Indeed, these differences pose challenges for the organisation of monitoring and evaluation of international co-operation in STI to address global challenges which policy makers need to take into consideration.

Governance options

Some options emerge from the literature and the case studies.

First, there is no single best funding and spending model. On the contrary, solutions seem highly dependent on the context and the global challenge concerned, on asymmetries in capacity, and, not least, on the nature of the collaborative effort (science, technology and/or innovation). Structural arrangements need to be flexible enough to be adapted as experience accumulates and circumstances change.

Second, the balance between core and project funding appears to be a fundamental issue for international STI funding. An appropriate balance is needed to allow for flexible approaches and to reach solutions that most often involve various trade-offs, for example between inclusiveness and efficiency in the priority-setting process or between broad accountability and efficient decision making, and to reduce endowment asymmetries.

Finally, questions of funding and spending for STI collaboration cannot be viewed in isolation. They need to be better integrated in discussions regarding the other governance dimensions in order to facilitate implementation.

9.4. Knowledge sharing and intellectual property: The international collaborative framework[7]

Intellectual property rights (IPRs) influence innovation and play an important role in diffusing knowledge and creating value (OECD, 2010b, p. 147). For example, they encourage investment in research and development (R&D) by enabling firms to recover investment costs. They may also stimulate the transfer of technologies that foster local innovation (Cavazos Cepeda *et al*., 2010; Park and Lippoldt, 2008).

However, IPRs that give owners exclusive rights may restrict timely innovative activities to address global challenges. For example, in drug development for neglected infectious diseases, an area with little funding, small markets and low levels of interest for owners of IPRs, patent laws do not help to stimulate further R&D. In such areas, it is especially important for researchers to maintain access to research data, tools and research with intellectual property (IP) protection. Circulation of knowledge is critical.

This section discusses international IP frameworks and the development of international collaborative frameworks and includes: *i)* an overview of international IP frameworks for each of the global challenges addressed; *ii)* concepts of collaboration and potential models for IP sharing; and *iii)* examples from the case studies. It concludes by proposing governance options.

International IP frameworks and issues for global challenges

IP and its ownership and protection affect R&D that is relevant to global challenges. International IP frameworks are governed by conventions and treaties, but national IP legislation varies and the role of IP varies in different sectors and industries. The range of types of IPRs and the diversity of stakeholders and interests create challenges for designing effective IP frameworks that facilitate international collaboration and help to address global challenges.

International IP frameworks

Currently, members of the World Trade Organization (WTO) must implement the minimum standard of IP protection specified by the Agreement on Trade-Related Aspects of Intellectual Property Rights (the TRIPS Agreement). Under this agreement, IP laws protect different types of intangible knowledge: patents, copyrights, trademarks, designs and trade secrets. For example, in wind-power technology, IPRs may include a patent for the wind turbine, a copyright for software related to aerodynamics, generators and blade controllers, a design for the appearance of the turbine, and a registered trademark for the brand. In addition, the manufacturing process is covered by the concept of trade secret (undisclosed commercial information).

There is no single approach to IPRs and global challenges. The role of patents and their monopoly effects differ depending on the industry, technology and products. Even within a single industry, such as the energy industry, the role of patents differs depending on the technology, from solar photovoltaic to biofuel to wind. The following illustrates some of the challenges and tensions created by current IP legislation in terms of global challenges: access to medicines, especially drugs for neglected diseases and generic pharmaceuticals; green technologies, including biofuels and renewable energy; and food security innovations such as protection of plant varieties and genetically modified crops.

International collaborative frameworks

Addressing global challenges requires frameworks and mechanisms to enable access to protected IP. IPRs are sometimes considered a barrier to international STI collaboration, as they exclude other parties from using IP-protected knowledge and exclusive rights. However, once IPRs are licensed, that knowledge can be used in several places simultaneously. Information sharing, technology transfer, and co-operation and collaboration are strategies to enhance research and innovation to address global challenges.

Some important trends in innovation processes may result in new IP management. As innovation processes and strategies became more open, the term "open innovation" was coined (Chesbrough, 2003). The shift toward openness requires more open IP management (*e.g.* licensing in from external sources, licensing out unused technologies) as opposed to keeping IPRs to defend against competition. In addition, not only firms but also individual consumers are increasingly able to innovate (von Hippel, 2005). Innovative end users often openly reveal their proprietary information to the public, and the information becomes a public good (Harhoff *et al*., 2003). In light of such trends, owners of IP restrict the use of their IP-protected information less and think about "what is best kept private and what is best freely revealed" (von Hippel, 2005, p. 117).

Some frameworks for international collaboration exist and illustrate strategies for making information on IP (*e.g.* owners, specifications, duration of rights, databases, etc.) and IPRs accessible. Patent offices, which catalogue and register IPRs, are one potential resource. IP licensing practices can be encouraged by reducing transaction costs, as is done through some databases. Multilateral collaboration mechanisms are in use in a few places, and there are experiments in open access.

Using patent offices to make IPR information accessible

IP information is first collected at national and regional patent offices, which have the resources and capacity to help accelerate registration and make information publicly available. Quellette (forthcoming, 2012) recently analysed the usefulness of disclosure requirements for patents in the life sciences.

For technologies in the area of climate change, the US Patent and Trademark Office's (USPTO's) accelerated registration programme, the Green Technology Pilot Program, is considered useful. Tran (2011) recently proposed making the Green Technology Pilot Program permanent in order to promote innovation and commercialisation of these technologies. In addition, the global online libraries – the European Patent Office's (EPO) "Espacenet" and Korea's Green IP project – demonstrate the effective use of patent offices for making IP information accessible.

Reducing transaction costs for IP licensing practices

Reducing transaction costs is important for enhancing technology transfer. The OECD, together with the EPO and the University of Tokyo, conducted a survey on the licensing out of patents (Pluvia Zuniga and Guellec, 2009). The survey identified the difficulty many companies face when they want to license their patents: the inability to identify potential licensees and partners. The most effective transfer requires a "package" of three components: IP information, relevant know-how and guidance for implementing the technology. Each component has associated costs, and the challenge in enhancing the attractiveness of technology transfer is to find ways to provide all three components in a cost-effective manner.

Using multilateral collaborative mechanisms

Collaborative mechanisms – patent pools, clearinghouses, consortiums and joint ventures – all have their advantages. Among these multilateral collaborative mechanisms, consortiums and joint ventures have the advantage of sharing goals and strategies among the partners. In addition, they take a relatively shorter time from planning and launching the project to producing results.

Patent pools with a clear philanthropic purpose have been established in the health and agriculture fields (Box 9.1). Well-tailored pools can serve economic and social goals such as public health and food security. However, patent pools have two drawbacks: potentially long timeframes for setting them up and challenges for putting the products on the market. The SARS and the Golden Rice patent pools illustrate these shortcomings. R&D initiatives such as patent pools take more time to establish than bilateral technology transfer but can make a significant impact when they are led and governed openly and efficiently. The patent pool framework is also important in the green technology area, as a means of creating a technology standard in industry, for example, for the receptacles used to charge electric vehicles.

Box 9.1. Collaborative mechanisms: Patent pools

A patent pool is an agreement between two or more patent owners to license one or more patents essential to a specific area of technology. Patents are licensed to third parties on a non-exclusive basis with a royalty payment, which is then distributed among the pool's patent owners. Licence agreements are generally administered by an independent entity as licensing agency. In the past, patent pools emerged for the aircraft industry, the electronics and telecommunication industries, the moving picture expert group, DVD-Video, DVD ROM, and third-generation mobile communication systems.

Patent pools have been often used to prevent some patent holders from preventing the development of new products or to establish a common technological standard for an industry. A more recent type of pool aims at overcoming transaction costs in order to serve public, rather than commercial, interests. Such patent pools with a clear philanthropic approach are more applicable in the life sciences (OECD, 2011b, Chapter 3), and ensure that particular products are made available on a not-for-profit basis. The following are examples of this type of patent pools.

Medicines Patent Pool for HIV medicines

The Medicines Patent Pool was established with the support of UNITAID in July 2010. It is the first patent pool aiming to make HIV medicines more affordable in developing countries and to facilitate the development of new medicines, including formulations for children. The original concept was proposed by the Consumer Project on Technology (currently Knowledge Ecology International, KEI) at the International AIDS Conference in Barcelona in 2002. In 2006, together with Médecins Sans Frontières, KEI proposed to UNITAID a patent pool for medicines. In 2008, the World Health Assembly at the World Health Organization (WHO) agreed that the pool was a feasible mechanism to accelerate the availability of low-cost newer medicines in developing countries. UNITAID's board decided to explore the possibility of a patent pool and, in December 2009, agreed to create the Medicines Patent Pool. UNITAID provides the funding for the pool.

The pool is a "one-stop shop" for patent holders and manufacturers of generic drugs. Multiple patents are "pooled" and licensed out by one entity in order to reduce transaction costs for all parties involved. Not only will the pool help speed up the process of providing urgently needed newer and improved HIV medicines at much more affordable prices, it will also foster the development of needed products that do not yet exist, such as certain fixed-dose combination pills containing two or more newer medicines in one pill. In 2011, the WHO expert committee on essential medicines endorsed a list of missing fixed-dose combinations submitted by the Medicines Patent Pool, UNITAID and WHO (WHO, 2011).

An attempt at a SARS patent pool

In response to the outbreak of severe acute respiratory syndrome (SARS), a network of laboratories set up by the WHO isolated the causative virus and the sequenced its genome (Verbeure *et al.*, 2006). The WHO set up a SARS consultation group, which proposed "that a strategy be developed, in consultation with stakeholders, to address potential SARS corona virus related intellectual property issues and, thus, enhance development of intervention approaches". The WHO SARS Consultation Group created an IP working group, which proposed in 2005 the pooling of all relevant patents in order to make SARS vaccine and treatments available in the event of a future pandemic.

The relevant parties have been identified, and an agreement of principle has been signed. However, the proposed SARS patent pool is not yet operating. Establishing patent pools in multinational settings is a long process; the Medicines Patent Pool took almost eight years to launch. When the relevant parties have signed a full agreement, the patent pool will be set up in the United States, followed by efforts to set up similar SARS pools elsewhere (Simon *et al.*, 2005).

Golden Rice Humanitarian Project

One of the most noted examples of humanitarian IP management involves vitamin A-enriched "golden rice". The Golden Rice project aimed at producing genetically modified "golden rice" in order to combat vitamin A deficiency. According to the WHO, vitamin A deficiency causes night blindness and overall blindness, and increases anaemia and risk of infection (WHO, 2009). The programme was developed mainly with public-sector funding and research, and approximately 30 companies and public institutions (universities) provided around 45 patents associated with golden rice.

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Box 9.1. Collaborative mechanisms: Patent pools *(cont'd)*

Access to IPRs was achieved in 2000. The key patent holders gathered and agreed to create a public-private partnership between the inventors and the agrichemicals company AstraZeneca (now Syngenta). The partnership facilitated access to a number of key technologies in the field of biotechnology and allowed the current Golden Rice Organization to grant licences, free of charge, to developing countries, with the right to sub-licences. The rice is expected to receive regulatory approval in the Philippines in 2013 and in Bangladesh in 2015 (Nayar, 2011). This example shows that even after the patent pool has been established, it may be many years before a product reaches the market.

Compared to patent pools, clearinghouses offer more flexibility and less formality. They are also easier and less costly to set up and generally require less administration. They provide a particularly useful mechanism if the IP covers the upstream technologies needed to develop future products (OECD, 2010b). In 2011, The World Intellectual Property Organization (WIPO), in co-operation with BIO Ventures for Global Health, launched "WIPO Re:Search", a clearinghouse for sharing IP and know-how in order to seek new treatments for neglected tropical diseases. However, clearinghouses work well only if the receiving parties identify their needs and participate in the search for the best way to obtain the needed technology.

Open access

Lastly, making research results available through private open-access initiatives such as the Glaxo SmithKline Open Lab or through national policy increases the potential for further research. Scientific progress requires the sharing of information – a commons of data, ideas and insights. In 2007 the OECD introduced guidelines to facilitate access to research from public funding (OECD, 2007). In 2009 a number of countries reported they were now adopting free-access policies for government databases.

Examples from the case studies

Some efforts are being made to establish international collaborative frameworks that make IP information accessible. The case studies illustrate some initiatives for sharing knowledge through licensing policy, patent pools and open data exchange.

Benefit sharing through licensing

The Global Carbon Capture and Storage Institute (Global CCS Institute) and the IAEA both have licensing policies that provide free access to IP-protected knowledge; however, in both cases, their free-access policy applies only to collaborators. For instance, partners of the Global CCS Institute can obtain IPRs resulting from their activities; however the IPRs are also to be made widely accessible to the members of the institute.

By contrast, the International Energy Agency (IEA) does not set any specific conditions on IPR ownership by its collaborators or project participants. IEA implementing agreements (IAs) have adopted a variety of arrangements and the Implementing Agreement Framework affords significant flexibility.

Collaborative mechanism: patent pools

The CGIAR uses patent pools as a collaborative mechanism. The case study shows that the CGIAR aims to "produce public goods at regional or global level" (Chapter 2). The CGIAR plays a major role in collecting, characterising and conserving plant genetic resources. The CGIAR's 15 international agricultural research centres maintain over 650 000 samples of crop, forage and agroforestry genetic resources in the public domain. The CGIAR gene banks hold in trust the genetic material of this vast number of food and agriculture crops, and the material is freely available.

Open data initiatives

The case studies introduce some open data initiatives. For example, the Group on Earth Observations, an international partnership, implements the principle of "full and open exchange of data". Its collection of data, the GEOSS Data Collection of Open Resource for Everyone, is an easily accessible pool of datasets and allows full and unrestricted access. Similarly, the Inter-American Institute for Global Change Research (IAI) aims to improve full and open exchange of scientific information and ensures free access to data generated by IAI-funded projects.

Governance options

The current and most widely accepted argument for IP protection is that the ability to exclude others from using protected knowledge creates incentives to invest in R&D and helps create opportunities for innovation. However, this argument needs to be reconsidered when effective and timely innovative actions are required and when innovation processes are becoming more open. Managing IPRs is critical for creating conditions for collaboration, because IPRs exclude other users from accessing and using the proprietary knowledge.

Sharing the benefits of IPRs in the context of STI collaboration to address global challenges could be promoted in the following four ways: *i)* using national authorities such as patent offices as a framework for sharing information on IP; *ii)* reducing the transaction costs associated with IP licensing; *iii)* establishing multilateral collaborative mechanisms; and *iv)* instituting open access policies.

Developing effective management strategies for IP resulting from research collaborations largely depends on learning how to respond to different configurations of influential factors: types of IPRs, sizes of private companies, sizes of sectors and public research organisations. Although IP legislation applies the same basic principles to all industries, intermediary markets for IP-protected knowledge can create flexible mechanisms that suit particular fields and stakeholders and thus facilitate beneficial IP exchange among different stakeholders.

Most collaborations relating to global challenges are promoted with the involvement of the public sector. Policy makers have an important role to play in helping to initiate and facilitate beneficial IP exchanges to create conditions for innovation. The broad concept of producing freely accessible "public goods" could be advanced through public policy regarding global challenges. Policy makers need to facilitate such open and flexible mechanisms for areas requiring effective and timely innovative efforts:

- They can lead open access initiatives by identifying the general framework and providing the initial funding for setting up such initiatives.
- They can bring together a wide range of players in the public and private sectors to set up collaborative IP mechanisms for creating efficiencies in the exchange of IP and for clearing IP blocks (*e.g.* through knowledge networks, open innovation). Policy makers need to encourage the private sector to work for the public interest.
- They can act as anti-trust authorities by examining the governance of IP transactions and patent pools with respect to competition and anti-trust laws.

9.5. Putting STI into practice: The need to bridge research and practice[8]

The process of transferring knowledge into action or practice is commonly referred to as "knowledge transfer" or "knowledge translation". It is broadly understood to encompass the exchange, synthesis and application of research results and other evidence between academic and practical settings (Graham *et al.*, 2006). This requires collaborative arrangements that combine the nature of the problem to be solved and the system of inquiry used to acquire and process information (Caplan, 1979). The academic literature stresses the importance of exchange of knowledge, "conceived as a virtuous circle of multiple-track engagement between knowledge producers (typically scientists, but potentially all academics) and knowledge users (typically policy makers, practitioners, stakeholders, businesses, social enterprises and others) so that the boundaries between the producers and users ultimately become merged" (Hagen, 2008, p. 113).

Using an "interactive model" rather than a "linear model" as the framework for the exchange of knowledge between research users and producers (Best and Holmes, 2010) implies complex interactions between researchers and users. The more sustained and intense the interaction between researchers and users, the more likely the research results will be used (Landry *et al.*, 2001).

The failure to translate research results into practice occurs often, but it is especially serious when it relates to global challenges. Multilateral STI collaborations are crucial for meeting global challenges, but to be fully effective, the means of delivering results is extremely important. This section stresses the need to consider four important dimensions of the effective bridging of research and practice. The first is communication throughout user and producer interactions so that practice will be informed by available knowledge. The second is brokering and thus facilitating at the individual level the hatching of knowledge brokers, and at the organisational level the creation of a "boundary organisation"[9] to improve communication, translation and diffusion of research results among all of a project's stakeholders. The third is training of STI producers and users, and more generally, actors of the knowledge-to-action process, to exchange knowledge. The fourth is to identify the relevant knowledge producers and knowledge users and bring them together in a comprehensive and communication-rich network.

Communication: Inclusive communication among stakeholders

Studies on international co-operation have shown that effectiveness suffers when communication fails to take place. For example, experts may assume, erroneously, that decision makers want a certain kind of information, or decision makers may assume that experts can readily furnish the information they want (Cash *et al.*, 2003). Successful STI research collaboration requires active, iterative and inclusive communication among experts, decision makers and end-users. Indeed, many communication channels have to be open to resolve the fundamental tension that arises for scientists and decision makers when science enters the policy arena: maintaining scientific credibility while ensuring political importance (Jasanoff, 1987).

The ability to mobilise knowledge for action is also hampered when communication is infrequent or takes place only at the outset of a project. Furthermore, effectiveness declines when stakeholders from either the expert or decision-making communities see themselves as excluded from discussions about the mobilisation of knowledge. Excluded parties often question the legitimacy of information emerging from such discussions, regardless of the information's credibility (Cash *et al*., 2003).

The IEA IAs appear to have created successful mechanisms for fostering multilateral communication of research results and information related to energy issues. These mechanisms take many forms. Collaboration and communication among IAs is fostered by the IEA Secretariat, which hosts co-ordination meetings for the different end-use sectors: buildings, electricity, industry and transport. Moreover, some IAs have created national teams or regularly scheduled meetings to address communication and co-ordination issues at the national level, and some have dedicated positions (such as a technical co-ordinator to facilitate communication with external stakeholders, see Chapter 7) charged with co-ordinating IA activities and outreach. Such initiatives appear to be conducive to better communication of research results through co-ordination activities, exchange of information and best practices, and the building of a community of practice.

Translation: The role of knowledge brokers

While putting knowledge into practice requires open channels of communication between experts, decision makers and end-users, it also requires the involvement of participants in discussions to understand each other. However, mutual understanding is often hindered by jargon, language, training, expectations and experience. The breaking down of such communication barriers is increasingly ensured by specific actors, called "knowledge brokers". Knowledge brokering encompasses "all the activity that links decision makers with researchers, facilitating their interaction so that they are able to better understand each other's goals and professional cultures, influence each other's work, forge new partnerships, and promote the use of research-based evidence in decision-making" (Lomas, 2007, p. 131; Canadian Health Services Research Foundation, 2003; CHSRF, 2003). The knowledge broker is an intermediary between users and scientists, and is fluent in both worlds.

Brokers have been very successful in the Pacific El Niño/Southern Oscillation Applications Center (PEAC) where they have worked with climate knowledge producers (at the university) and users (often public officials) to increase the usability of seasonal climate forecasting in planning and decision making. For instance, PEAC devised mechanisms to produce forecasts in which final outputs used language that would be readily understood by target audiences. In this case, studies showed that the language of historical analogy was more understandable than the language of probabilities. PEAC used scientists proficient in both languages who could translate between them and identified the most effective language (Cash *et al.*, 2003, 2006).

Knowledge brokering activities can involve either individuals or organisations. Their central role in the knowledge translation process suggests the need to encourage the education and training of professionals who are at least literate but ideally fluent in the contexts of both knowledge production and use (Jacobs *et al*., 2005). At the organisational level, the "boundary organisations" play the role of broker. These organisations operate in a dynamic environment, attempting to strengthen linkages between science and policy by facilitating a two-way flow of information.

Empowering people: Training producers/users to transfer knowledge

Knowledge transfer activities are not necessarily the primary focus of researchers, while policy experts and practitioners are not necessarily sensitive to research results. The expectations of policy makers, practitioners and scientists are usually very different, owing to difference in their cultural settings and institutional constraints. Culturally, scientists rely on rigorous analysis of facts and data sets, while policy makers look for the best available information at the time, ideally in a well-packaged, easily applied format. This suggests the need to train producers and users in knowledge transfer as a requirement for the successful exchange of information or knowledge between scientists and policy makers, and more generally, end users.

A successful example is found in an initiative launched by the Inter-American Institute for Global Change Research (IAI). In 1999, it launched its interdisciplinary training institutes to promote the human dimensions of environmental change and the consequent need for a science–policy interface to ensure that relevant scientific findings are accessible to and usable by policy makers. Their success in fostering communication between natural and social scientists and promoting multinational and multidisciplinary collaboration led the IAI to plan further institutes.

International STI networks and communities

In the management literature, networks are regarded as the emerging organisational mode in environments of complex technologies and rapid technological change. In science- and technology-based fields, the advantages of diverse sources of information and resources are considerable. Not surprisingly, as the commercialisation of knowledge has assumed greater importance in economic growth, collaboration across organisational boundaries has become more commonplace. Inter-organisational networks allow organisations to pool or exchange resources and jointly develop new ideas and skills. In fields where scientific or technological progress is developing rapidly, and the sources of knowledge are widely distributed, no single organisation has all the necessary skills to comprehend and put to use all areas of progress and bring innovations to market (Powell and Grodal, 2005). Networks also play an important role in mediating different views among collaborating partners.

Networks are constituted not only by organisations but also by actors who are a part of a community or engaged in a community activity. Science policy and management scholars have identified two types of communities. Based on the work of Hass (1991), Court and Young (2004) describe how epistemic communities − colleagues who share a similar approach or a similar position on an issue and maintain contact with each other across their various locations and fields − create new channels for information and discussing new perspectives. From the management science perspective, communities of practice (CoP) have been identified as a key factor in the learning process. According to Oborn *et al.* (2010, p. 10), "Brown and Duguid (1991) develop the idea of evolving CoP to account for organizational interactions that take place between fluid and interpretative groups as opposed to bounded individuals."

To produce good results, international networks formed to put STI into practice must integrate the various types of communities concerned and offer them a permanent platform for interaction. Cohesion across national and cultural borders can be created through the sharing of scientific expertise within the community, constantly updated in conferences, workshops, etc., and a common understanding of the need to act and of the general direction of the required action. Well-functioning epistemic communities can influence policy making in all countries involved, provided that their members are linked not only internationally, but also to their home governments.[10]

The leadership dimension

Nevertheless, spontaneously organised networks of individuals, organisations or communities are only one aspect of successful governance of international STI collaboration. Another key element of efficient translation of STI into practice at the global level is leadership to co-ordinate the activities that will put research into practice. In most of the cases presented in this volume, the organisation did not have an explicit leadership role but played a supportive role, often directed at horizontal co-operation at a given stage of the knowledge cycle process. An exception is the CGIAR, according to its mission statement as redefined in December 2009: "To reduce poverty and hunger, improve human health and nutrition, and enhance ecosystem resilience through high-quality international agricultural research, partnership *and leadership.*" The same is true to some extent of the IAEA, whose "core organisational principle is related to *global leadership* in one specific discipline (atomic energy and related technologies) that can be used for different purposes" (CGIAR, 2010) although it does not focus on a given global challenge.

The diversity of actors involved in putting STI into practice, combined with the need to draw on local, dispersed and often independent practitioners, points to the necessity of clearly attributing leadership or a mandate to an existing or *ad hoc* institution and empowering it for building and fostering networks. The comprehensiveness and responsiveness of the concerned networks will be crucial for the time needed for putting research into practice to address global challenges.

Governance options

The literature review clearly points to a knowledge-to-action cycle, an interactive and multidirectional process involving many different actors and activities. The case studies highlight that the main organisational pitfalls of existing institutions that address global challenges are: *i)* missing or dysfunctional links at critical points of the process; and *ii)* the lack of a clearly identified leader in charge of building and activating the network of stakeholders. Putting STI more effectively into practice to address global challenges would thus require:

- Identifying relevant knowledge producers (epistemic communities) and knowledge users (communities of practice, policy makers) to bring them together in a comprehensive and dynamic network that is active at all of the stages of research.
- Enhancing communication throughout the network so that practice is informed by available knowledge and knowledge gaps in STI can be identified and addressed.
- Facilitating at the individual level the development of knowledge brokers and at the organisational level the creation of "boundary organisations" to enhance the communication, translation and diffusion of research results among all of a project's stakeholders.

- Training STI producers and users, and more generally actors in the knowledge-to-action process, to exchange knowledge.

9.6. STI capacity building[11]

Global challenges by definition do not stop at national borders; they have an impact on all countries. In many instances, such as infectious diseases or the effects of climate change, negative consequences are more acute in developing countries. Comprehensive solutions to global challenges require a co-ordinated international response, but also require all partners to help find scientific and technological solutions in their own communities and geographical regions. Efforts are needed to: *i)* improve STI capacities in a multidisciplinary global context; and *ii)* ensure that STI capacities are linked to societal needs and national development goals. Attention should focus not only on how much STI is produced, but also on how STI can be assimilated and put to use in local contexts. This section first considers the characterisation of capacity building. It then looks at how the multiple aspects of STI can be used to understand and support capacity building. Next, important elements arising from the case studies are presented, followed by some governance options.

"Broad" vs. "narrow" view

Despite the enthusiasm for and wide use of the concept of capacity building, there is little empirical evidence on its scope and influence (World Bank, 2009) and little agreement on ways to identify and measure the capacity-building process. This makes it difficult to assess capacity gaps between partners and evaluate the impacts of capacity-building programmes (Duane, 2007). Nevertheless, the literature differentiates several levels of capacity building: the individual level, the organisational and community level, and the national and institutional level. Young and Kannemeyer (2001) have shown that the main approaches to capacity building are networking, training, research partnership and institution building.

To understand the different rationales behind STI collaborations and their effects on capacity building it is useful to distinguish between a "narrow" and a "broad" STI co-operation paradigm (Boekholt *et al.*, 2009). The former puts a priority on achieving research excellence, with a focus on building scientific and technological capacities *stricto sensu*. The latter has scientific and non-scientific objectives in order to reach broad policy goals and tackle societal challenges. Although the "narrow" mode predominates in international research collaborations, the urgency of global challenges calls for a "broader" approach to international STI collaborations. This requires combining scientific and broader sources of knowledge and reconsideration of the role of partners from developing countries.

In the "narrow" paradigm, one of the goals of scientific research collaboration is the realisation of "state of the art" research, and this was a goal of all of the case studies in this volume. However, too exclusive a focus on scientific capacities entails the risk of a linear, mechanistic interpretation of the relations between advanced economies – generally the suppliers of research – and developing countries – the recipients. It is now realised that while it is important to produce "state of the art" research, its integration and interaction with other sources of knowledge in a sector or country are equally crucial (Hall and Dijkman, 2006).

Traditional support for STI capacity building is similar to technical assistance, with the provision of either training or hardware (Horton *et al.*, 2003). While there has been much progress in the last decades in several sectors, the limitations of an approach based solely on technical assistance and scientific capacities have often been stressed (WBI, 2006). There is a need for a more systemic approach, a "broad" paradigm involving broader sources of knowledge and interactions among a wide range of stakeholders (universities, firms, farmers, government organisations, etc.) through which individuals and organisations learn, put new ways of working to use, and open up new technological pathways (Klerkx *et al.*, 2009; Lundvall *et al.*, 2009). This socioeconomic and institutional context is constantly changing, and capacity building also needs to evolve as the context and the needs change.

Addressing the multiple dimensions of STI capacities

Building STI capacities is by definition a multidimensional process encompassing science, technology and innovation. Most practical approaches to capacity building remain largely focused on scientific capacities in developing countries. While these investments are essential, capacity building also involves strengthening many skills and activities, including the ability to search for, select and use existing scientific and technological knowledge and products and the ability to develop new solutions or innovate through the combination of different types of knowledge. To this end, developing countries should be seen as dynamic partners and should be helped in their efforts to strengthen their local system of innovation.

This is now happening. In particular, the BRIICS economies (Brazil, the Russian Federation, India, Indonesia, the People's Republic of China, South Africa) are becoming important partners in scientific and innovation networks (OECD, 2011a). In their case, there is a visible shift from unidirectional transfers of knowledge and technology – from advanced to developing countries – towards joint investments, reciprocity and a search for mutual interests (Cornwall and Eade, 2010). The evidence shows that collaborative research between scientists in advanced and developing countries is increasing, and that these activities are building advanced scientific capacity in participating countries (Wagner *et al*., 2001; Strigl, 2007; Wagner, 2008). The success of a few emerging economies should nonetheless not hide the fact that developing countries are at a clear scientific and technical disadvantage in terms of trained scientists, number of scientific publications and patents, and investment in R&D (UNESCO, 2010).

Meeting global challenges requires not only scientific progress, but also the successful application of new technologies. However, technology diffusion and adoption appear to require substantial and well-directed technological efforts (Lall, 2001). For example, science and technology promotion by the government played an important role in the promotion of economic growth and industrialisation in Japan and later in many successful East Asian economies (Amsden and Hikino, 1993).

As developing countries build up their domestic scientific and technological capacities, they become better able to access, assess, use and assimilate foreign technologies. Cohen and Levinthal (1989, 1990) proposed the notion of "absorptive capacity" to refer to a firm's ability to utilise outside knowledge efficiently. They argued that this capacity is a function of the firm's own investment in R&D. For Lim (2006) absorptive capacity is primarily a function of the connectedness of a firm's scientists to counterparts outside the firm. This suggests the need for active involvement in scientific and technological networks. This concept has entered the literature on developing countries (Criscuolo and

Narula, 2002; Zahra and George, 2002). Authors generally agree that absorptive capacity is critical and that it is important for developing countries to build their absorptive capacities by focusing on exploiting existing technologies. In practice however, this is almost exclusively associated with a narrow view of STI linked to the accumulation of human capital and infrastructure building.

Innovative capacity refers to the ability to develop alternative solutions to existing problems by combining a variety of knowledge sources. Innovation takes place in productive enterprises (*i.e.* firms and farms) but also in other organisational and institutional structures. A focus on innovative capacities highlights the importance of combining different types of knowledge through networking, interactive learning and collaboration (Lundvall, 1992; Edquist, 1997). Strengthening innovative capacities requires proactive and committed partnerships among multiple actors with a view to the accumulation of scientific knowledge, the absorption of existing technologies, and solutions based on new combinations of knowledge. This last element is crucial, as recent work has shown that technology acquisition is more effective when coupled with domestic innovation (Marin and Bell, 2006; Marin and Sasidharan, 2008). Building innovative capacities requires effective partnerships and inclusive, collaborative networks as well as shared infrastructures, not only physical but also digital and institutional.

Lessons from the case studies

Nature of capacity-building efforts

Capacity building is a core mission for three of the organisations studied in this volume: GEO, CGIAR and IAI. GEO made capacity building one of its strategic goals. It intends to "build the capacity of individuals, institutions and infrastructures to benefit from and contribute to Global Earth Observation System of Systems (GEOSS), particularly in developing countries" (GEO, 2009). Capacity building has been explicitly recognised in the GEO structure from its inception, and has a clear and well-defined strategy and target. The GEO has designated a Capacity Building Committee to strengthen the capacities of all members. Similarly, CGIAR allocates about 20% of its budget to fund capacity building and technology transfer. The IAI has closely coupled its efforts to support interdisciplinary, collaborative research with the goal of building scientific capacity throughout the Americas. To this end, the IAI developed new ways to integrate different institutional, programmatic, financial, educational and scientific objectives, and it has assigned two of its 13 staff to manage capacity building. For the other organisations studied, however, capacity building is not an explicit goal. They pursue the advancement of scientific research in terms of equal contributions rather than assisting partners with lower STI capacities.

Nevertheless, in the majority of organisations described in the case studies, developed and developing countries collaborate on topics of mutual interest. These collaborations do not always take into account the weaker STI capacities of less developed countries. A notable exception is the CGIAR's research centres which conduct adaptive research tailored to local agricultural conditions. In other instances (*e.g.* the IAEA), the participation of developing countries has depended on their ability to contribute to the task. From the case studies, it emerges that differences in partners' scientific and technological capacities were often viewed as an obstacle to research of a high standard. This view of the need for "equal capacities" in order to deliver high-quality research gives a clear advantage to middle-income countries. It puts low-income developing countries at a clear disadvantage and could lead to further marginalisation. More importantly, perhaps, this method, based on the "narrow" paradigm defined above, is bound to miss possibilities for interactive learning and exchange of different types of knowledge that are crucial to tackle the complexity of global challenges.

Types of capacity building

The most frequently used channel for capacity building is the training of scientists and researchers, followed closely by technology transfer. Almost all initiatives mention training scientists as a key element in their strategy. For instance, training and education activities are a core mission of the IAI. Over the last ten years, it has supported thousands of students and professionals, through fellowships, workshops and research opportunities. But, with the exception of CGIAR and IAI, the strengthening of local institutions to ensure the assimilation and adaptation of foreign science and technology has been infrequent.

All seven initiatives described in the case studies pursue high-quality, "state of the art" research. As the impacts of global challenges expand beyond the domain of pure science, the need for interdisciplinary, problem-centred, multi-stakeholder research becomes apparent. The mixing of participants from various disciplines and different backgrounds is critical to address both geographic and disciplinary cross-border issues related to global challenges. In that direction, the IAI has built global environmental networks in the Americas involving social and natural scientists, institutional and local decision makers to build trust and common understanding and facilitate collaboration. Other initiatives also understand the importance of broader participation of stakeholders. Indeed, partnering with a wide range of beneficiaries and stakeholders seems to generate a demand for capacities to meet the needs created by the STI gap in developing countries. In general, however, all of the initiatives appear to pay insufficient attention to inter-disciplinarity.

Lack of vision and leadership

The evidence from the case studies in this volume suggests that in many cases the selection of tools for capacity building is done on an *ad hoc* basis rather than as the result of a well-structured strategy. For capacity building to be successful, it needs to be relevant to the country and situation to which it is directed. In this respect, developing countries must determine and drive activities from conception to implementation to evaluation. The European and Developing Countries Clinical Trials Partnership (EDCTP) is an example of good practice in the area of capacity building through international co-operation to address global challenges (Mattee *et al.*, 2009; Zumla *et al.*, 2010). It includes elements favouring a more equal partnership among partners by including recipient countries in the decision process. It shows, as well, that mainstreaming capacity building is an important element in the success of international co-operation involving participants with different capacities, and that the integration of regional research networks in the priority-setting process, together with consideration for demand-led capacity building, leads to successful results (Box 9.2).

Box 9.2. A true partnership: The EDCTP

The European and Developing Countries Clinical Trials Partnership (EDCTP) was founded in 2003 by the European Parliament and Council. It is a partnership of 14 European Union (EU) member states, Norway, Switzerland, and 43 developing countries, and was formed to fund acceleration of new clinical trial interventions in the sub-Saharan African region.

The EDCTP capacity building strategy in Africa is unique, as it offers full support only to African scientists, promotes African ownership of projects, and receives backing from regional networks of excellence in sub-Saharan Africa. It receives scientific advice from the Partnership Board, half of whose membership is African. Research networks are pursued among research institutions with complementary research expertise that provide training and mentorship to less endowed centres in their regions to bring them to the level at which they can participate more effectively in multi-centre clinical trials. This will provide a good working environment for health research scientists and help to retain them in Africa. In addition, the insistence on stronger institutions building capacity in less endowed ones within the clinical trials has helped to ensure that there is equitable distribution of funds for capacity building in Africa.

Source: Matee *et al.* (2009).

Governance options

From the literature and the case studies, it appears that capacity building involves more than strengthening individual capacities to conduct scientific research. It also involves support for many skills and activities, including elements of the ability to search for, select and use scientific and technological knowledge and products; the ability to develop the means to improve existing scientific and technological knowledge to address local needs; the development of structures and partnerships to build domestic innovation capacities; and the management and governance experience necessary to organise and manage international co-operation among partners with different levels of STI capacities. Given this, effective capacity building should formulate explicit targets, goals and ways to measure the results. Greater effectiveness could be achieved through:

- A shift in emphasis from one-way technology transfer and scientific training to participatory learning and capacity building.
- A reassessment of the current approach focused on producing “state of the art” research to include the establishment of mechanisms for STI initiatives to be more closely linked to local needs and stakeholder demands.
- The active engagement of recipients in the conception, implementation and evaluation of capacity-building activities that directly concern them.

9.7. Conclusion

Despite the urgency of many global challenges, some of which are the subject of the case studies, there is no single, coherent governance mechanism for dealing with the issues they raise. They present a complex picture and show the need to deal with specific situations and environmental factors. This does not mean that there are no common themes, best practices or necessary conditions for success. The case studies and the review of the literature indicate some recurrent themes and dimensions that appear to shape the environment for STI and make it more favourable to co-ordinated efforts for tackling global problems.

At the outset, a comprehensive vision will increase the likelihood of successful international collaboration. Priority setting should therefore be closely linked to budgetary issues and negotiations, while greater representation of states with weaker STI capacities, international civil society and organisations will lead to more equitable outcomes. It is also necessary to identify pertinent producers and users of knowledge and to bring them together in a comprehensive network, with an emphasis on communication, translation and utilisation of research results among all stakeholders. Mechanisms to facilitate exchange and adoption of knowledge will be needed. Special attention should be paid to the selection of intellectual property regimes (from exclusive patents to open access policies), to differences in partners' capacities, and to linking STI initiatives closely to local needs and stakeholders' demands.

The policy co-ordination required to meet global challenges entails strong structures that are sufficiently empowered to have a certain level of independence from the individual interests of the various stakeholders and actors (whether states, scientific communities, practitioners, business entities, civil society or NGOs) but that still ensure broad access to priority-setting processes. Such structures need to be able to weigh and resist external interests and flexible enough to adapt as experience accumulates or the environment changes. Successful management of STI to address global challenges implies autonomy in the decision process and a level of independence from funding bodies. This autonomy, in turn, implies the definition of clear priorities so that the results achieved can be evaluated, internally or externally. This will increase the project's legitimacy. A large consensus among stakeholders on these priorities will facilitate participatory evaluation and self-assessment.

The global dimension of the public goods to be produced means that issues related to resource asymmetries between the different actors must be addressed in order to avoid capture by "vested" interests, to balance efficiency, legitimacy and accountability concerns, and to achieve broad implementation of solutions. Transparency, legitimacy and fairness are required at all stages in order to involve a wide range of stakeholders and facilitate the creation and adoption of the results achieved by the STI systems concerned.

The resolution of the various trade-offs that necessarily arise in such processes may suggest a case for structures composed of a permanent core associated with project-based mechanisms. They would have broad fund-raising capabilities, could gather and disseminate information, ensure informal and formal communication on a broad scale and act both as forums for discussion and as STI policy makers or co-ordinators. Such structures might also be composed of "networks of networks" that bring stakeholders together as needed or of existing international entities that can act as boundary organisations, depending on the global challenge to be addressed.

The importance of information and transparency for mobilising STI effectively implies a substantial and continuous effort to sustain broad awareness of ongoing processes to enhance communication between and among different types of stakeholders in order to overcome information asymmetries and to avoid duplication, and to make rules and procedures widely available to the public at large.

Together, the literature reviews and the case studies point to strong leadership as a necessary condition of effective STI policy making, funding and implementation at the international level. Given the number and diversity of stakeholders and interests, the large range of existing efforts and the scarcity of resources, clearly identified decision makers and a flexible structure seem most likely to energise co-ordinated STI efforts and channel them to address global challenges efficiently.

This chapter has analysed five dimensions of governance relating to the implementation of policies for dealing with global challenges. What remains to be done is to address more precisely whether the options proposed are in harmony or in conflict with one other. Ideally, any decision should take into account the positive and negative expected effects of the instruments chosen. The "policy mix" should be able to provide an overall net benefit, given the inherent uncertainties and limitations. In order to implement strategies, policy makers should also consider how interdependent actors shape the overall performances of a project to tackle global challenges.

In designing governance mechanisms to address global challenges through STI co-operation, policy makers, and more generally all the stakeholders of a project, could benefit from considering the whole range of activities to be pursued and the linkages to be formed on the way to the desired outcomes. Two types of linkages must be considered, *within* and *across* governance dimensions. Two examples can illustrate their interdependency. As an example of a linkage *within* governance dimensions, the need for broad and active participation by relevant stakeholders to ensure legitimacy of the priority-setting process carries the risk of generating an increasing number of priorities and can lead to potentially incompatible or counterproductive inputs in the decision process. In terms of linkages *across* governance dimensions, the diversity of actors involved in the process, combined with the need to draw on dispersed and often independent practitioners, calls for an interactive and multi-directional process of knowledge exchange in order to put knowledge into practice. To achieve this goal, that diversity has to be acknowledged in the priority-setting process; funding schemes and IPR regimes have to be designed to facilitate interaction; and differences in terms of STI capacities have to be addressed to manage international co-operation among diverse partners. These varied interactions among governance dimensions call for more detailed analysis stressing trade-offs and feedback within and across governance dimensions.

The main conclusions concerning governance options, summarised below, are presented as a list, but should be understood not as independent but rather as interdependent aspects to be balanced:

- Broad and active participation of relevant stakeholders and permanent support for information flows to achieve common understanding and consensus are paramount.
- A mix of different approaches, such as bottom-up and top-down, supply-led and demand-informed, is required to avoid possible bias in the selection process.
- Priority setting, budgetary and implementation issues must be linked from the outset.
- Structural arrangements need to be flexible enough to be adapted to an increased knowledge base and to any other changes.
- An adequate balance between core and project funding appears to be a fundamental condition for sustained and dependable international STI funding and a necessary tool to overcome endowment asymmetries.
- Solutions most often involve various trade-offs arising, for example, between capacity building and one-shot efficiency or between broad accountability and efficient decision-making.

- Questions of funding and spending for STI collaborations cannot be viewed in isolation but need to be fully integrated with the other governance dimensions to facilitate their implementation.
- The association of a wide range of players in the public and private sectors is needed to set up collaborative IP mechanisms to improve efficiencies in the exchange of IP, clearing IP blocking positions, and favouring open access initiatives;
- Communication throughout the relevant networks must be enhanced so that practice can be informed by available knowledge and knowledge gaps in STI can be identified and addressed.
- Hatching of knowledge brokers must be facilitated to enhance communication, translation and diffusion of research results among all the stakeholders of a project.
- STI producers and users, in the knowledge-to-action process, should be trained in knowledge exchange.

Notes

1. This section draws on input provided by Wolfgang Polt and Florian Holzinger of the Joanneum Research Institute. They would like to thank the Austrian Federal Ministry for Science and Research and the Austrian Federal Ministry for Transport, Innovation and Technology for funding their research.

2. "Capture is the control of the regulatory process by those whom it is supposed to regulate or by a narrow subset of those affected by regulation, with the consequence that regulatory outcomes favor the narrow 'few' at the expenses of society as a whole." (Mattli and Woods 2009, p. 12)

3. This section draws on input provided by Magnus Gulbrandsen and Frode Hovland Søreide of the University of Oslo and by Egil Kallerud and Lisa Scordato of the Nordic Institute for Studies in Innovation, Research and Education. They would like to thank the Norwegian Ministry of Education for funding their research.

4. See High Level Group for Joint Programming (2010) for a comparison of the advantages and disadvantages of alternative funding tools.

5. On this point, see for instance Gornitzka and Langfeldt (2008).

6. The public sector definitely plays an important role in addressing market failures and in producing the public goods needed to mitigate and alleviate the effects of global challenges.

7. This section draws on input provided by Mineko Mohri of the OECD Secretariat.

8. This section draws on input provided by Andreas Stamm and Aurelia Figueroa (German Development Institute) with support from Harriet Harden-Davies (Australian Academy of Technological Sciences and Engineering (ATSE). The German Development Institute would like to thank the German Federal Ministry of Research and Education/ Bundesministerium für Bildung und Forschung (BMBF) for funding their research.

9. "Boundary organisations" act as brokers between science and policy. They attempt to link scientific research to policy decisions and public action by initiating two-way interactions.

10. For a review of knowledge management and the role of communities, see Amin and Roberts (2008).

11. This section draws on input provided by Erika Kraemer-Mbula (Institute for Economic Research on Innovation, and Imraan Saloojee (Department of Science and Technology of South Africa). They would like to thank the Department of Science and Technology for funding their research.

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