This article was published in 'Science and Technology Policy for Development, Dialogues at the Interface' by Louk Box and Rutger Engelhard (eds) (2006) Anthem Press London UK.

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International collaboration in science and technology: promises and pitfalls

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International collaborations represent a growing share of scientific and technical activities. In contrast with national programmes and projects, connections at the international level are systems of communication, facilitated by ICTs, that are often difficult to identify. Policy makers are faced with the question of how to support, benefit from and exploit them. The networks created by international collaboration in science and technology (ICST) offer opportunities for developing countries to acquire knowledge for local development, but there are few guidelines on how to manage such networked systems. The potential for missteps and the obstacles to joining networks are significant. This chapter describes the dynamics of ICST, and offers a framework for decision making about how to use the opportunities they offer to provide the demand for development.

1 Introduction

Various studies have demonstrated that international collaboration in science and technology (ICST) is growing.[2] The number of citations to articles resulting from international collaborations has grown faster than those referring to domestic collaborations.[3] Much of the ICST is beyond the direct control of research funding agencies and donors, and the question of when and why these organizations choose to invest in ICST is discussed. Indeed, the bulk of funding commitments within scientific or technical projects are made without reference to their international or funding status.

This chapter argues that the bulk of ICST activities can best be presented and managed as a *network of communications.* It continues with a description of networked operations of

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[2] Most of the studies have used the addresses of the co-authors of articles (Narin, 1991; Luukkonen *et al.*, 1992, 1993; Miquel and Okubo, 1994; Doré *et al.*, 1996; Georghiou, 1998; Glänzel, 2001; Wagner and Leydesdorff, 2005).

[3] Persson *et al.* (2004), Narin *et al.* (1991).

collaboration at the global level and delineates steps to tap into this set of activities. Finally, it discusses the implications for the networked organization of ICST for future policy and research planning.

2 Why is international collaboration growing?

The growth in ICST is occurring within all fields of science and technology. Factors such as the ease of travel and access to ICTs contribute to, but do not cause this growth in international collaborations. ICTs and low-cost travel reduce the opportunity costs of linking together for joint experimentation and data sharing. Many of today's technology applications that facilitate international research collaboration, such as 'grid computing' for online engineering projects,[4] or open source software engineering, were not available 10 years ago. However, in order to justify the time and extra effort involved in international collaboration, researchers must see clear benefits in collaborative knowledge creation.

There appear to be five major reasons why researchers engage in international collaborative activities: (1) they can increase their visibility among peers and exploit complementary capabilities;[5] (2) they are able to share the costs of projects that are large in scale or scope; (3) they are able to access or share expensive physical resources; (4) by working together, they can achieve greater leverage by sharing their data; and (5) they need to exchange ideas in order to encourage greater creativity.[6]

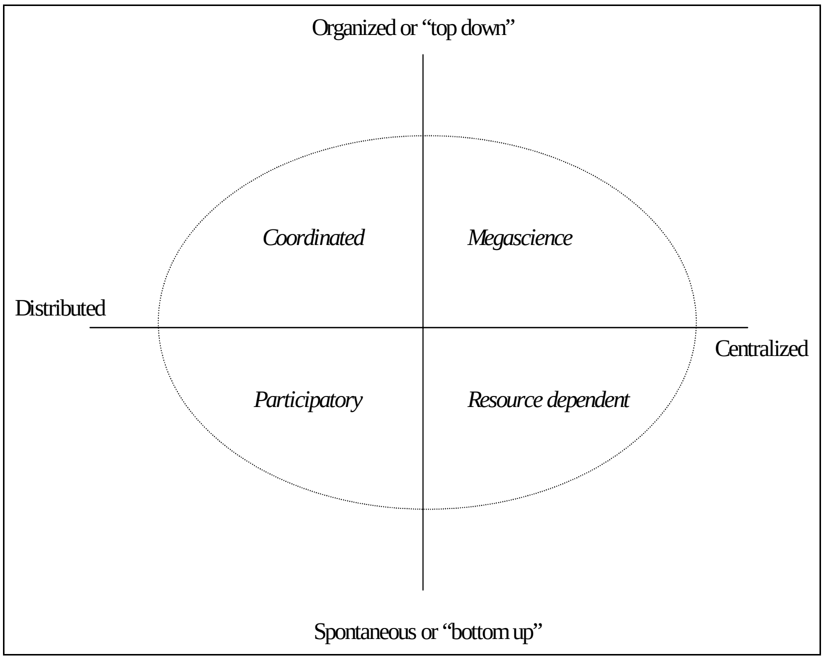

Figure 1. Schematic representation of factors relating to the organization of ICST.
Source: Wagner *et al.* (2000).

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4 Grid computing offers a means of solving massive computational problems using large numbers of computers arranged as clusters embedded in a distributed telecommunications infrastructure. Grid computing has the design goal of solving problems too big for any single supercomputer, while retaining the flexibility to work on multiple smaller problems (Centipedia.com).

5 Wagner and Leydesdorff (2005).

6 Wagner (1997; 2002).

These sets of motivating factors are juxtaposed in figure 1. The vertical axis represents organizing features related to funding, extending from highly 'top-down' activities organized by institutions or organizations, to 'bottom-up' activities initiated by researchers themselves as they seek out partners for collaboration based on their own needs and interests. The horizontal axis represents the range of locations of research, from widely distributed to highly centralized. The juxtaposition creates four quadrants that can guide us in considering ways to understand and increase participation in international collaboration.

Researchers also self-organize 'spontaneously' into collaborative teams from the bottom up. They may work together to share, or may meet while accessing relatively rare or localized resources, such as botanists studying plants in a rainforest. This places them in the *resource-dependent* quadrant. Geophysics and soil sciences are two fields that might be considered as falling into this quadrant. Researchers can also self-select fellow collaborators independently of other factors like shared equipment, resources, or the interest of funding institutions, simply because the collaborator offers new ideas or complementary capabilities. This type of bottom-up collaboration, which could be termed participatory, occurs in fields such as mathematics or economics. It could also include cases where researchers of the same nationality living in different countries seek each other out. There are many cases of developing country scientists working abroad who collaborate with their compatriots.[7]

Each of these collaborative dynamics presents different challenges to policy makers or researchers who want to participate in ICST. Before exploring these dynamics in detail, it is useful to consider the motivation of the agencies that fund ICST, since they also influence the direction of research and the extent of collaboration.

3 Why do governments fund international collaboration?

Funding for ICST is committed by governments (through agencies, institutes, universities and special programmes), by quasi-governmental bodies that spend government money (such as the World Bank), and by non-governmental organizations (such as philanthropic groups). These three groups of 'funders' finance R&D for a variety of reasons, including the need to meet larger policy goals (national defence, foreign relations), to meet specific public missions (energy, health), and to promote knowledge creation (basic science or engineering), which is often tied to the rationale of enabling economic growth.

Funders spend some of their budgets on dedicated international collaboration, but in most cases, this tends to be a small percentage of their funding activities.[8] Research suggests that between 5 and 10% of all R&D funds are set aside for ICST. Quasi-governmental bodies with an international mission may spend a higher proportion of their budgets on ICST, but the net amounts for curiosity-driven research often are not high. NGOs commit considerable funds to S&T-related topics, but these are often highly mission-specific (such as malaria vaccine or

7 Wagner *et al*. (2001).

8 The exception here is the EU, which spends most of its funds on international collaborations at the European level. While non-European countries are not restricted from participating, very few developing countries participate in EU-funded projects. There is a set-aside for development aid for research (see Wagner *et al*., 2001).

crop research). The slice of funds available for open bidding and committed to 'open science' and technology is quite low.[9]

Figure 2 is a visualization of the role of funders in determining the subjects or organization of ICST. Funds dedicated to ICST, committed in projects such as the International Space Station or CERN, have been called 'corporate' partnerships or collaborations.[10] These are formal 'means to an end' research collaborations that are initiated by more than one group towards a common goal. When viewed in terms of overall spending, these activities represent a small percentage of all ICST – the 'tip of the iceberg' in figure 2. 'Team collaborations' are formalized through joint proposals or shared research resources, but they are not formally funded as such. Activities sponsored within the CGIAR centres or the international Human Frontier Science Program fall within this category. Finally, the bulk of ICST funds are spent within a diverse category of 'interpersonal collaborations' that includes informal partnerships, workshops, database development, fellowships, and many other activities.

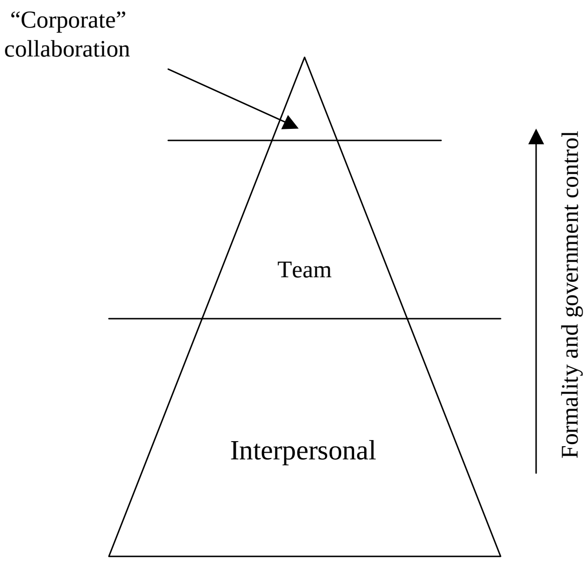

Figure 2. Funding for ICST collaborations.

As ICST becomes less formal, governments and other funding agencies have less control over how funds are spent and who collaborates in the research. Thus, efforts to seek formal collaborations through foreign ministries are often disappointing because the funds available are very small. Even more disappointing is the fact that formal diplomatic-level S&T agreements often have no funds or authority attached to them. This is because the allocation of the bulk of the research monies is beyond the control of the diplomats. Even if they wanted to fund a specific programme with researchers from a specific country, the chances of finding and targeting funds in this way are minimal.[11]

9 Wagner *et al*. (2000), Wagner (2002).
10 Smith and Katz (2000).
11 Scientists themselves are often resistant to seeing funds set aside for targeted purposes or earmarked for work with a specific country, since they see this as undermining the peer-reviewed process of identifying and funding science based on excellence as the principal criterion.

4 Networking: a system of communications within ICST

If the bulk of ICST funds are allocated and spent by researchers as they take part in informal and team research activities, this has significant implications for anyone seeking to join these activities. How can these less formal activities be identified? How can policy makers and researchers find opportunities to initiate or join collaborations? How can interested researchers make themselves attractive candidates for membership on such teams? For the purpose of providing a framework for considering these questions, let us consider ICST as a system of communications.

When international science is considered as a series of communicating networks, it is possible to explain and even illustrate the dynamics of these relationships. Consider each co-authorship as representing a link between two researchers. Using this as a structure, it is possible to illustrate the network and then to 'see' changes in science and technology during the 1990s – changes that have significant and encouraging implications for developing countries. Between 1990 and 2000, at the regional level, researchers from more countries joined in collaborative research, as evidenced by co-authorships in internationally recognized peer-reviewed journals. Figures 3 and 4 show the network of linkages among African authors in 1990 and 2000, respectively. In 2000 the network is much better integrated, and shows the emerging knowledge hubs. Countries that were peripheral in 1990 are more closely tied into the network at the regional level in 2000.

The same pattern towards the integration of peripheral countries and the strengthening of links at the regional level can be shown to have occurred during the 1990s for all regions of the world except the Middle East.[12] This suggests a shift in the organization of science during the decade away from a 'centre-periphery' model with Germany, the UK and the USA at the centre of world science, with only a handful of industrialized countries as collaborators, to the emergence of hubs in all regions of the world. These regional hubs have served to draw in even smaller, more peripheral countries into an extended global network.

For researchers in developing countries, the benefit of joining a global network, even if only by linking to a neighbouring country, is that they are just a 'handshake' away from other members of the network. These networks create links in science so that researchers are only three or four steps away from each other in a broad global network of knowledge creators.[13] These links increase the chances of knowledge exchange in multiple directions, from advanced to developing countries, and vice versa. Local links also increase the likelihood that knowledge creation focuses on issues relevant to the developing countries rather than on issues that concern only scientists in advanced countries.

[12] In the Middle East, links have deteriorated at both regional and global levels (see Wagner and Leydesdorff, 2003).

[13] Newman (2001).

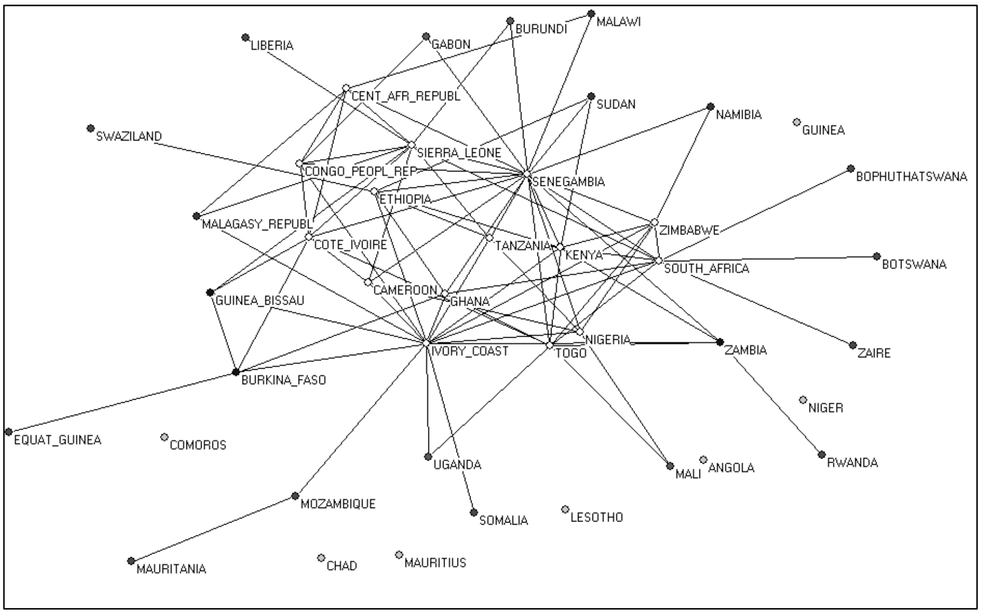

Figure 3. Network of co-authorships among African authors in 1990.
Source: Wagner and Leydesdorff (2003).

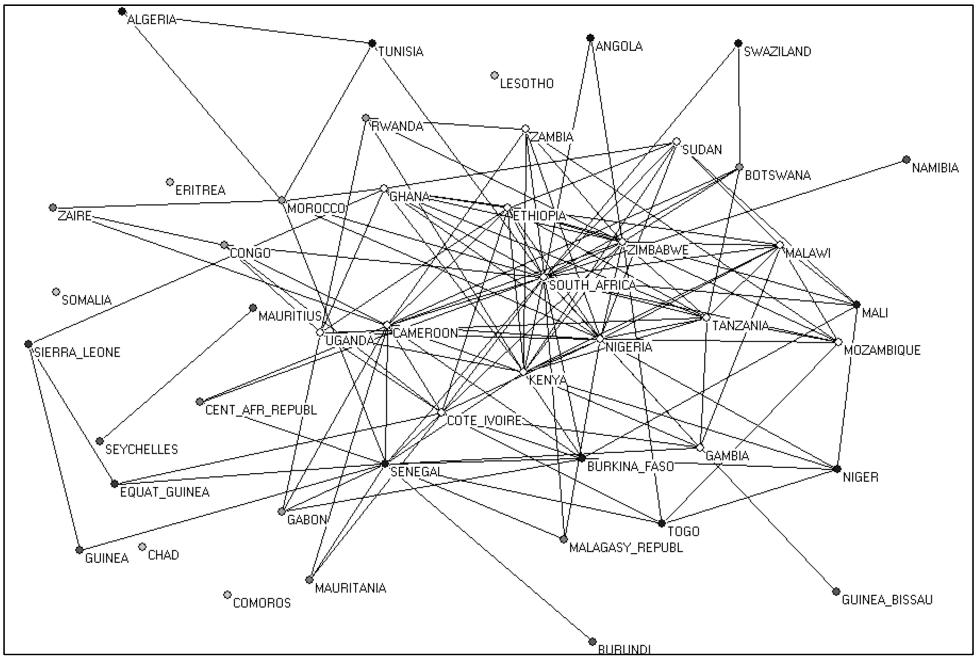

Figure 4. Network of co-authorships among African authors in 2000.
Source: Wagner and Leydesdorff (2003).

The networks operating at the international level are not ‘flat’, but have a structure and hierarchy. The largest and most scientifically advanced countries remain strong core members of the international system. However, the question for developing countries is not how to get into collaborations with Germany, the UK or the US, but how to take applicable knowledge from the network (no matter where it is located), make it relevant to local needs and problems, and tie it down. The process of tying down or retaining knowledge at the local level requires some institutional capacity.[14]

Within the overall structure of the international networks created by collaborative projects, the creation and communication of knowledge can be thought of as taking place at four levels:

- *Local*: building knowledge within laboratories and local research institutes that address local needs, e.g. a technical college that can help local farmers to solve problems.
- *National*: meeting national goals, building the economy, government-funded programmes to grow research capabilities.
- *Regional*: addressing problems, sharing knowledge among states with common problems, e.g. the APEC programme on environmental sustainability.
- *Global*: sharing resources, data and findings across national boundaries, e.g. 'megascience' projects such as the Large Hadron Collider and distributed collaborations like the Human Genome Project.

Figure 5 presents a visualization of these four levels of knowledge creation and communication.

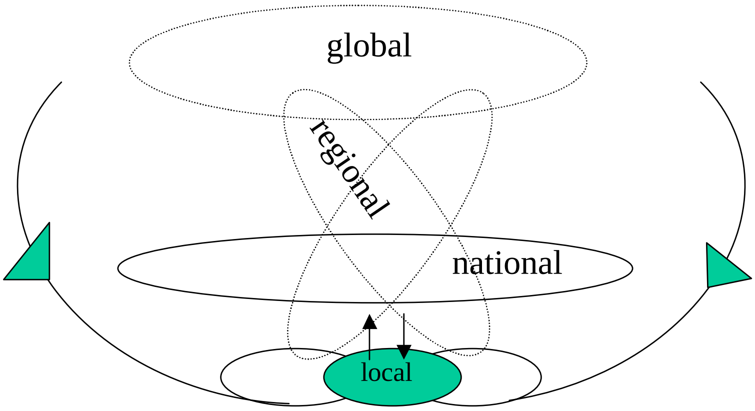

Figure 5. Science and technology collaboration operate on a number of levels, international collaboration is a system of communications on top of other levels.

As suggested by the dotted lines in figure 5, the 'global level' does not exist as a separate entity. There is no global ministry of science coordinating efforts at the international level. Relationships at the global level often self-organize through the initiatives of the researchers themselves. The links among researchers across nations operate through communications that tie the information and knowledge at the national and local levels, strengthening them. It is possible to use these ties to create a virtual neighbourhood of researchers who can share knowledge. For some new entrants to the network, however, the question becomes one of how to identify these links in the network, tap into them, and use the knowledge well.

5 Making strategic decisions for participation in ICST

The ability of any country or researcher to join the ICST network depends on two things – the resources they can bring to bear on a problem or question, and their attractiveness as a

14 InterAcademy Council (2004), UN Millennium Project (2005).

partner. While it may be possible to construct collaboration as a policy initiative, or to negotiate a diplomatic agreement to cooperate in science, these efforts will only be sustainable if they are supported by good science or solid technical skills. For this reason, policy makers or researchers seeking to develop an ICST strategy need to coordinate their plans with domestic efforts to improve domestic research and development. At the national level, in order to make the most of the international networks, government and research institutions should strengthen their links using face-to-face meetings and information technologies. Individual researchers should be regarded as 'stakeholders' in the process of decision making about ICST investments, since they are the ones who will be creating the connections to the broader network.

When making explicit plans for ICST, in order to be an attractive partner, it is important to build from strengths or to offer a unique resource. This is important because self-organizing networks look for partners rather than onlookers. 'Strengths' to offer can include, for example, a field of science or engineering where national researchers are publishing and being cited, a good database or a natural (or created) resource that scientists or engineers are interested in, or an innovative approach to a shared problem of interest to two or more countries.[15]

In any of these cases, selections must be made about where to place emphasis in order to build the critical mass to enable collaboration. Regional linkages can be highly productive and have the added advantage of involving less cost in terms of travel and cultural connections. Looking for and building regional hubs makes sense, and indeed, appears to be the way a number of countries have improved their connections over the past 15 years. Finally, bringing back the results of ICST to meet national needs is crucial to sustainability.

An ICST strategy needs both 'top-down' (government planned) and 'bottom-up' (interests of scientists and engineers) approaches. Identifying areas of common interest requires stakeholder analysis of where national capabilities lie, and determining what might be done with science or engineering. This can be accomplished through meetings that focus on identifying national needs, such as health care, security, energy, the environment, etc.

Once these ICST links are made, government policy can help to ensure that knowledge is made to flow back into local research institutes, and between them and industry. This feedback loop, or local network, is critical to being able to tie down the knowledge gained and maintain ICST participation in the future. This can be done by creating a database of developments and making it available on the web, or disseminating information in a newsletter or at public forums in order to gain recognition for the results.

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[15] Clearly, for some countries that have little to offer in terms of strengths or indigenous capabilities, it may be the role of donor agencies to help develop capacities with the specific goal of encouraging ICST links. There are a number of cases where a developing country with a natural resource has been able to build this successfully into ICST.

Government influence over commitments and outcomes

High → Medium → Low

		Big Science	Resource-dependent	Coordinated	Participatory
High ↓	Government policy considerations	Carefully consider possible participation in strategic international collaborations already underway, such as genomics or physics research	Focus funds on a specific area where Vietnamese expertise or unique resource would attract collaboration, such as fisheries	Examine research within the region where Vietnamese researchers could work virtually with others via the Internet	Provide basic science fund, peer-reviewed, provided to best proposals for basic research; add funds for international conferences
Medium ↓	Actions for research institutions to consider	Negotiate with other Vietnamese institutions about effective allocation of participation	Examine possibilities for creating centers of excellence in resource-dependent sciences based on location, capabilities	Build broadband access to encourage virtual collaboration; build specialized database to support research	Create internal committees of researchers to review and support ICST activities
Low	Action at the level of the individual researcher	If big science is attractive, connect to regional researchers already working within the project	Create a team and seek funding from specialized non-governmental organization	Place good research on the Internet; seek to publish papers at the international level	Seek funds from the government or non-governmental organization to participate in international conferences and symposia; propose to host as well

Table 1. Special considerations for stakeholders in ICST decision making

6 *Restructuring policy to tap knowledge networks*

The knowledge networks that emerged during the 1990s and early 2000s now dominate relationships in international science and technology. Traditional policy approaches based on national systems of innovation and research, using a linear concept of knowledge creation (from basic research to the marketplace), and counting inputs (such as achieving 3% of GDP devoted to research spending), are inadequate to manage science and technology. Increasingly, ICST research is networked, spans disciplines and political borders, and includes participants from different sectors (such as university and industry researchers working on common projects). Each of these factors adds a measure of complexity to those seeking to do policy planning, monitoring and evaluation.

Indeed, the benefits to developing countries of the networked world of science and technology are twofold. First, knowledge may be easier to access. Researchers are more interconnected, creating the possibility that a ‘local search’ among professional acquaintances may turn up relevant information that can be useful locally. The marketplace of ideas is more accessible than it has been in the past. On the other hand, for developing countries using S&T to aid development, the network offers the possibility that many of the institutions that constituted a 20th-century concept of national systems of innovation – and that some countries with scarce resources have tried to imitate – are no longer needed in order to innovate. Some functions of an innovation system may be accessed virtually or shared with neighbouring countries in ways that reduce the up-front investment costs. (Does every scientifically advanced country need a synchrotron? A patent office? A metrology office?)

This chapter has argued that ICST for development should build on local strengths, be tied to critical domestic needs, and have a clear capacity building component. Selections should include a 'top-down' government perspective on national needs, and the 'bottom-up' interests of researchers. Identifying these areas of common interest, and building on knowledge-based motivational factors, will help to ensure that knowledge is tied down at the local level. Understanding and tapping into the network of interconnections among scientists and engineers at the global level can offer both knowledge and functionality to a developing country seeking to build an S&T base for development. Planning for interconnections at the local, national, regional and international levels, rather than thinking strictly about a 'national' system, will have the greatest pay-off in terms of providing demand for development.

References

Doré, J.-C., Ojasoo, T. and Okubo, Y. (1996) Correspondence factorial analysis of the publication patterns of 48 countries over the period 1981–1992. *J. American Society for Information Science*, 47: 588–602.

Georghiou, L. (1998) Global cooperation in research, *Research Policy*, 27: 611–626.

Glänzel, W. (2001) National characteristics in international scientific co-authorship relations. *Scientometrics*, 51: 69–115.

InterAcademy Council (2004) *Inventing a Better Future: A Strategy for Building Worldwide Capacities in Science and Technology*. Amsterdam: InterAcademy Council. www.interacademycouncil.net/report.asp?id=6258

Laudel, G. (2001) Collaboration, creativity and rewards: Why and how scientists collaborate. *Int. J. Technology Management*, 22: 762–781.

Luukkonen, T., Persson, O. and Sivertsen, G. (1992) Understanding patterns of international scientific cooperation, *Science, Technology and Human Values*, 17(1): 101–126.

Luukonen, T., Tijssen, R.J.W., Persson, O. and Silversten, G. (1993) The measurement of international scientific collaboration, *Scientometrics* 28(1): 15–36.

Miquel, J. F. and Okubo, Y. (1994) Structure of international collaboration in science, Part II: Comparisons of profiles in countries using a link indicator, *Scientometrics*, 29: 271–297.

Narin, F. (1991) *Globalization of research, scholarly information, and patents: ten year trends,* Proceedings of the North American Serials Interest Group (NASIF) 6th Annual Conference, June 1991, *The Serials Librarian*, 21.

Newman, M. (2001) Who is the best connected scientist? A study of scientific co-authorship networks. Scientific collaboration networks, I: Network construction and fundamental results, *Phys. Rev*. E 64: 016131; II: Shortest paths, weighted networks, and centrality, *Phys Rev* E 64: 016132; condmat/0010296.

Persson, O., Glänzel, W. and Danell, R. (2004) *Inflationary Bibliometric Values: The Role of Scientific Collaboration and the Need for Relative Indicators in Evaluative Studies*, Draft obtained from W. Glänzel, January 2004.

Smith, D. and Katz, J.S. (2000) *Collaborative Approaches to Research*, HEFCE Fund Review of Research Policy and Funding, Final Report, University of Sussex.

Wagner, C. (1997) *International Cooperation in Research and Development: An Inventory of U.S. Government Spending and a Framework for Measuring Benefits*. Santa Monica, CA: RAND.

Wagner, C. (2002) Science and foreign policy: The elusive partnership, *Science and Public Policy*, 29(6): 409–417.

Wagner, C., Brahmakulam, I., Jackson, B., Wong, A. and Yoda, T. (2001) *Science and Technology Collaboration: Building Capacity in Developing Countries?* MR-1357.0-WB. Santa Monica, CA: RAND.

Wagner, C. and Leydesdorff, L. (2003) Mapping global science using international co-authorships: A comparison of 1990 and 2000, in: J. Guohua *et al.* (Eds.), *Proc. 9th Int. Conf. on Scientometrics and Informetrics.* Dalian: Dalian University of Technology Press, pp.330–340.

Wagner, C. and Leydesdorff, L. (2005) Mapping the network of global science: Comparing international co-authorships from 1990 to 2000. *Int. J. Technology and Globalization*, 1(2).

Wagner, C., Yezril, A. and Hassell, S. (2000) *International Cooperation in Research and Development: An Update to an Inventory of US Government Spending*, MR-1248, Santa Monica, CA: RAND.

UN Millennium Project (2005) *Innovation: Applying Knowledge in Development*. New York: UNDP/Earthscan.