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Emerging Technologies and Opportunities for International Science and Technology Foresight

Patrick Van Zwanenberg, Adrian Ely, Andy Stirling

Foresight

STEPS centre

About this paper

This background paper focuses on the potential role that international science and technology 'foresight-type' activities might play in informing decision-making processes about innovation, development and emerging technologies. Two, predominantly national-level, foresight type activities are discussed, 'technology foresight' and 'technology assessment'. Experiences with these approaches are quite diverse but over time there has been a discernible shift in many countries away from reductive and expert-based exercises to more plural processes in which wider sets of assumptions have been articulated about problems, desired futures and the social purposes of technology. Foresight-type activities have only occasionally been conducted at the international level but this paper argues that there may be scope for conceiving of international foresight activities as a mechanism for articulating and framing development 'needs', and for bringing these to bear on innovation actors. This would, however require considerable attention to how foresight-type activities are designed and conducted, and the complexities of dealing with a very large array of global actors and perspectives.

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About the Manifesto project

In 1970 a radical document called The Sussex Manifesto helped shape modern thinking on science and technology for development. Forty years on, we live in a highly globalised, interconnected and yet privatised world. We have witnessed unprecedented advances in science and technology, the rise of Asia and ever-shifting patterns of inequality. What kind of science and technology for development Manifesto is needed for today's world? The STEPS Centre is creating a new manifesto with one of the authors of the original, Professor Geoff Oldham. Seeking to bring cutting-edge ideas and some Southern perspectives to current policy, the New Manifesto will recommend new ways of linking science and innovation to development for a more sustainable, equitable and resilient future.

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About the STEPS Centre

The STEPS Centre (Social, Technological and Environmental Pathways to Sustainability) is an interdisciplinary global research and policy engagement hub that unites development studies with science and technology studies. Based at the Institute of Development Studies and SPRU Science and Technology Policy Research at the University of Sussex, with partners in Africa, Asia and Latin America, we are funded by the Economic and Social Research Council.

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INTRODUCTION

The original Sussex Manifesto (Singer et al 1970) emphasized the need for developing countries to build their own indigenous capabilities for science and technology, and to develop the planning tools required to ensure that these capabilities were employed in response to their own specific needs. It also stressed that:

> The 'need' for science and technology may only be perceived if one takes a long-term, perspective view of development because many R&D projects take a long time to give results (Singer et al 1970: paragraph 117).

Since then, the role of 'perspective planning methods' to identify *needs*, which the manifesto argued must be 'used in much greater detail than is normally done', has become mainstream in many parts of the world, whilst remaining underutilised in others. In the intervening years as the world has become more interconnected, there have been increasing examples of international initiatives to apply science, technology and innovation to development objectives, and the potential impacts of increasingly pervasive emerging technologies have led to a need to re-think some of these questions.

This background paper focuses on the potential role that international science and technology 'foresight type' activities might play in informing decision-making processes about innovation, development and emerging technologies. The discussion covers two 'foresight type' activities, both of which are formal processes for informing the governance of research and innovation. These are:

- *technology foresight*, typically defined as 'systematic and explicit attempts to identify areas of strategic research and emerging generic technologies likely to yield the greatest economic and social benefits'
- *technology assessment*, typically defined as: 'anticipation of impacts and feedbacks in order to reduce the human and social costs of learning how to handle technology in society by trial and error.'

Essentially, technology foresight (TF) aims to open up space for thinking about new possibilities. The idea is to inform priority setting and investment in research and technology development, in both the public and private sectors, and more generally to contribute to shaping agendas, debates and decision-making about science and technology. Technology assessment (TA), on the other hand, is concerned with selecting, or modifying developments. The idea is to anticipate and evaluate technological impacts, so as to inform decision-making processes about projects or programmes with a strong technological component, and sometimes to contribute to broader agenda building. Kuhlmann et al (1999) have argued that the combination of traditions from TF and TA (they also include R&D evaluation) can lead to higher synergies in what they term 'strategic intelligence', and this is also the stance taken in this paper.

National experiences with TF and TA approaches are quite diverse but over time both approaches, TA in particular, have evolved in many national settings; in general shifting somewhat from expert-led, reductive processes with associated scientistic notions of 'objective neutrality' to somewhat more plural processes in which a broader array of participants are

involved, and wider sets of assumptions about, for example, what the problems are, or what desired futures might be, are brought into appraisal. This paper briefly reviews those developments and considers what scope there might be to conduct elements of these within international institutions, with an explicit focus on development.

Currently, TF and TA activities are largely undertaken at national levels, predominantly in the industrialised countries. The reason for this is straightforward enough: decisions about priority setting and the allocation of R&D, at least in the public sphere, are largely a national-level activity. There are, however, various international institutions that have a development agenda, and that undertake general assessments of say agriculture, or climate change, and these often include some kind of technology assessment/foresight-type activity, though perhaps not always explicitly labelled as such. The outputs of such international institutions, though rarely linked *directly* to R&D funding decisions, may nevertheless have long-run indirect effects on the priority setting and resource allocation decisions undertaken by a range of public and private actors. The argument outlined here is that there may be scope for conceiving of international foresight activities as a mechanism for constructing, framing and articulating development 'needs', and for bringing these to bear on innovation actors. This would, however require considerable attention to how foresight activities are designed and conducted, and the difficulties of dealing with a very large array of global actors and perspectives.

TECHNOLOGY ASSESSMENT

Technology Assessment (TA), emerged initially in the USA during the 1960s, and was institutionalized in the Office of Technology Assessment (OTA) in 1972, and subsequently in several other OECD countries in the 1970s and 1980s, though with comparatively less generous funding. TA institutions outside of the USA were often modeled on the OTA and for example often served the legislature. TA emerged partly as a consequence of the political fallout from the environmental and anti-nuclear movements, and what Wynne (1975) described as the anxious desire within US intellectual and policy circles for political consensus. Amidst sharply conflicting arguments about the effects of certain technologies, the institutionalization of TA activities was seen by its proponents as providing an objective, indeed a scientific, analysis of the impacts of a technology in order to assist subsequent political decision-making about which technologies should be funded for development. Thus in 1976 Brooks noted that: 'Ideally the concept of TA is that it should forecast, at least on a probabilistic basis, the full spectrum of possible consequences of technological advance, leaving to the political process the actual choice among the alternative policies in the light of the best available knowledge of their likely consequences' (Brooks 1976: 20).

TA has been used with a focus on either a specific technology or group of technologies, or on technology related problems and has covered a wide range of social, economic, legal, political, cultural and ecological effects. No standard methods were used. Early efforts, reflecting the technocratic ideology of TA's champions, focused on statistical and mathematical models, but a variety of quantitative and qualitative methods have been used. These range from brainstorming, literature research, document analysis, expert consultation, case studies, cross-impact analysis, cost/benefit analysis, trend extrapolation, decision trees, Delphi methods, computer simulations, and scenario development. The most common data sources were surveys of existing literature supplemented by 'opinions of experts' based on discussions, simple questionnaires or Delphi techniques (Dylander 1980).

Following the institutionalization of TA in the OTA, it rapidly became clear, in practice as well as in principle, that it was not possible to fully anticipate impacts, in part because, as Guston and Sarewitz note, '...consequences emerge not from the static attributes of a fully formed technology, but from the complex co-production that simultaneously and continually molds both technology and social context' (2002: 8). Furthermore, assessment was anything but neutral and objective. Critics note how technology assessments were crucially dependent on non-technical and often implicit framing commitments, for example, about the nature of the problems requiring assessment, the scope of appraisal, the types of effects to assess, the appropriate methods to employ, and so on (Wynne 1975). In the US, stakeholder involvement and other forms of participation were methods OTA developed to counter accusations of lack of social neutrality, especially in definitional decisions such as over what technologies to assess, and the kinds of issues to include and exclude from assessment.

The early technocratic vision of TA is nevertheless alive and well, especially in its more narrow incarnations as risk analysis or environmental impact assessment. These often share the over-optimism that all important impacts can and will be anticipated, and are organised around the same decisionist model of TA in which 'objective' science precedes subsequent political processes (*cf.* the distinction between risk assessment and risk management). Risk analysis is however often far more narrowly conceived than early TA. It tends to focus on one particular implementation of a technology, such as a specific plant or specific product, rather than a technology as a whole, let alone technological options, and is usually confined to direct physical effects of the investigated technological product or process, rather than broader social impacts or more indirect impacts. Such highly reductionist approaches to assessment of 'risk' are increasingly practiced in international institutions whose global remit inevitably involves development concerns, for example in the food standard setting process of the Codex Alimentarius Commssion.

TA as a more general policy tool declined in the USA after the OTA was 'defunded' by a Republican Congress under the first Clinton administration in 1995 (Houghton 1995). But TA continues to be practiced elsewhere, especially in Europe. Since the 1980s, European traditions of TA have evolved to include more broad-based, inclusive forms of appraisal that are often far more sensitive than their more expert-analytical predecessors to the negotiation and justification of prior framing commitments. For example, Participatory Technology Assessment, developed largely in Denmark – like the broadly similar 'interactive technology assessment' developed in the Netherlands in the 1980s –was a reaction to a demand for a more socially oriented approach to technology and for a greater scope for public influence and participation in decision-making. Participatory Technology Assessment involved politicians, NGOs, trade unions, journalists, scientists, technology developers, and lay people; it experimented with different methods to represent that variety of actor (e.g. dialogue fora, focus groups, and consensus conferences), and was concerned to make interests and values explicit. Often, the analytic product became of relatively minor importance compared to the interactive process, and the aim of agenda building, articulating views about new technology and fostering public debates on technology. Participatory forms of TA have become widespread in many industrialised countries, although not necessarily linked to subsequent decision-making about the allocation of resources.

Other branches of TA have emerged. In the Netherlands, 'constructive' TA sought to introduce not just a broader scope of issues into assessment activities and a more extensive array of participants, but crucially aimed at influencing both parliamentary decisions as well as on-going technological design decisions (Rip et al 1995). 'Interactive' TA has stressed the importance of

involving all relevant stakeholders in analysis so as to offer insights into the extent to which possible development paths are considered meaningful to those actors and to offset the normative biases inherent in less plural processes. It explicitly aims to open up not only a wide array of possible solution strategies but also the definitions of the problem at issue. Loeber describes how one Dutch interactive TA on crop protection issues went beyond the ideal of doing justice to the plurality of perspectives that defined the crop protection problem, but also intended that the project should result in a fundamental policy reframing of that problem (Loeber 2004).

In summary, TA, at least in some jurisdictions and under some guises, has expanded noticeably from a technocratic, expert-led analytical exercise to encompass more pluralistic and reflexive approaches that allow greater attention to the framing of agendas, problem definitions, and the breadth of inputs. Performed sensitively, TA can open up and illuminate options and opportunities in the technical or social sense in ways that are sensitive to the (albeit indirectly constructed) values and aspirations of otherwise marginalised actors. Yet as Van Eijndhoven (1997) usefully reminds us, TA is largely a Parliamentary advisory activity and does not directly influence the power base behind technological choices. Actors may therefore always conclude that they are not helped (or not helped effectively enough) by such additional information.

TECHNOLOGY FORESIGHT

Unlike TA, Technology Foresight (TF) has from the outset been far more closely integrated with innovation actors, although it remains a narrower, expert-led activity by comparison with the more recent TA initiatives. Large firms have engaged in TF activities as part of their strategic management process for decades but it has only been since the 1980s and 1990s that it became an organised part of national governments' science and technology policies. TF emerged out of 'technological forecasting' activities in the 1960s and 1970s which were extrapolative and predictive; they assumed a single discrete and determinate future. TF, however, is a less deterministic endeavour. As described by Grupp and Linstone, 'Foresight takes into account that there is not a single future. Depending on action or non-action at present, many futures are possible, but only one of them will happen. To select a desirable future and to facilitate its realization is one of the aims of technology policy.' (Grupp and Linstone 1999)

TF involves a combination of analysis and communication processes in which stakeholders participate in a forward-looking exercise. Typically, in some of the early foresight initiatives, such as the first UK foresight initiative conducted in the mid 1990s, panels of industry stakeholders together with government and academic members would identify key trends and issues within an economic sector, develop scenarios, and consult using workshops and Delphi techniques. The aim was to identify the likely social, economic and market trends in a sector over a period of say 10-20 years and the developments in science, engineering, technology and infrastructure required to best address identified 'needs'. Delphi techniques involve successive iterations of a given questionnaire, to show convergence of opinions and to identify dissent or non-convergence. Experts are encouraged to revise their earlier answers in light of the replies of other members of their panel. Thus the methods aim to bring about consensus and convergence. Recommendations seek, typically, to identify possibilities where there is a convergence of scientific and technical feasibility and potential social and economic benefits. Thus, TF, at least in its early incarnations was concerned to anticipate 'optimal' technological pathways that met expert-defined economic and social 'needs' of a national economy. Such

approaches often obscured key framing choices about contending technological pathways and futures, and the social purposes, needs, benefits, risks and priorities for technology.

Early foresight often focused on so-called critical technologies that were regarded as key to future competitive economic development. The rationale was one of market failure - of firms having excessively short horizons such that intervention is necessary to stimulate them to take a longer view and consequently to afford a higher priority to research (Georghiou 2001). The key actors involved were from academia and industry, particularly those able to span the gap between the two institutions. A key driver of TF was increasingly competitive markets and the need to set priorities for funding science and technology in the face of restricted budgets and increasing competition, but there has not always been a direct link established with funding mechanisms.

Many commentators have argued that it is not just the *product*, i.e. the identification of 'promising' technologies that is important in TF but rather that the *process* of facilitating networking and information flows among actors is just as, or even more, important a goal. For example, Martin and Johnston (1999) point to a variety of process benefits: greater concentration on the longer-term future, a degree of consensus on desirable futures, commitment to turning ideas into action, and enhanced communication and co-ordination among companies, among researchers and between researchers, users, and funders. Martin and Johnston argue that TF offers a means of 'wiring up' and strengthening the connections within the national innovation system so that knowledge can flow more freely among the constituent actors, and the system as a whole.

More recent foresight exercises have been somewhat broader in scope and process than the first initiatives. There has been a shift away from the use of the Delphi technique towards panel or scenario-based approaches, for example, and a broader range of stakeholders beyond industry and the research community, has been involved. TF has covered not just 'critical' technologies, but also technological activities (e.g. food, health) and increasingly the societal context of technology applications (e.g. aging populations). This shift is represented by Georghiou (2001) as a 'third generation' of foresight in which the focus on market failure is replaced by one of system failure or socio-economic problem solving. This has involved greater input from a wider variety of social actors such as NGOs and parts of government beyond those directly responsible for science and technology. As van Langenhove puts it, contemporary TF now 'can be made by a broad set of methods, ranging from desktop research, interactive brainstorm processes, to broad participatory arrangements. The scope for foresights can be any issue of societal relevance, in which knowledge, science and/or technology plays a considerable role.' (2002:45) Experiments with 'social technology foresight' have aimed to bring a wider range of social values and objectives to bear on the definition of the objectives of technology policy, and on the mapping of alternative possible paths of technology development and their implications (See Todt and Lojan 1998). Thus, as with TA there has been an evident broadening of TF with some movement towards the development of broader, more pluralistic approaches to appraisal, and the aim of contributing to a more normative debate about technological futures. Certainly calls for such movement exist. Renn, for example, stresses that in addition to expert-based elements of foresight, designed to open up space for examining technological opportunities, the inclusion of wider groups of stakeholders to address uncertainty and ambiguity (i.e. conflicting values) over possible futures should be a key part of foresight (Renn 2002). There are clear tensions however between the often explicit goal in TF of building consensus and the equally understandable goal of articulating a wide variety of visions of the future.

INTERNATIONAL FORESIGHT AND ASSESSMENT

Technology Foresight remains largely a national endeavour. There are a few institutions conducting regional or multi-economy foresight exercises such as the European Commission's Institute for Prospective Technological Studies, UNIDO's foresight programme focused on Latin America and the Caribbean, and a Center for Technology foresight under the umbrella of Asia-Pacific Economic Cooperation (APEC). Commentators readily acknowledge the difficulties involved in conducting foresight at a multi-economy scale. These include those of adjusting to the increasing actor, stakeholder, and context complexity and to the different sets of worldviews and value sets represented; the difficulty of developing meaningful strategy-relevant discussions, as the number and diversity of interests represented increases; and the underdevelopment of formal institutions which are empowered and endowed with resources to respond to the types of outputs that typically emerge from foresight exercises (IPTS-JRC 2002).

Technology Assessment also remains a largely national endeavor. This is partly due to the fact that the established institutional niche (as already noted) is predominantly in association with national level parliaments – and that such legislative functions do not occur at other governance levels. Where they do (as in the European Parliament), there have emerged incipient technology assessment bodies like the European Science and Technology Options Assessment office (STOA).[1] Other intergovernmental bodies with remits addressing the informing of technology choice do from time to time conduct exercises with many characteristics of more traditional technical and expert-based technology assessment. An example would be the periodic reviews of technological mitigation and adaptation options undertaken by the Intergovernmental Panel on Climate Change (IPCC 2007). However, these kinds of initiative tend to fall far short of the breadth and depth of functions and issues addressed by bodies such as the US OTA (in its day) or its European offshoots, Teknologiradet in Denmark[2] and Rathenau Instituut[3] in the Netherlands.

As noted earlier, some other international institutions, such as Codex, also conduct aspects of TA, in this case risk analysis of food and agricultural technologies. The UN Commission on Science and Technology for Development, established in 1992, is responsible, amongst other things, for 'initiating arrangements for the early identification and assessment of new scientific and technological developments which may adversely affect the development process as well as those which may have specific and potential importance for that process ...' (UN Resolution 34/218, 1979) As such, it appears to come closest to an international institution concerned with development with an explicit responsibility for technology assessment at international level. Thus far, however, only very limited TA-like activities appear to have been conducted, covering biotechnology and ICT, and these have been fairly traditional exercises based on high level meetings and expert-based reviews (See for example UNCTAD 2004; Commission on Science and Technology for Development 2005).

When considering the globalised nature of innovation systems, this general lack of international institutional capacity for broad-based technology assessment is quite striking. It is particularly stark because many of the most important tensions around the unintended or unforeseen consequences of technological change actually arise at an international level, where options

[1] See STOA website at http://www.europarl.europa.eu/stoa/about/default_en.htm (9 September 2009)
[2] See Teknologiradet website at http://www.tekno.dk/subpage.php3?page=forside.php3&language=uk (9 September 2009)
[3] See Rathenau Instituut website at http://www.rathenauinstituut.com/default.asp?steID=2 (9 September 2009)

developed in certain specific contexts are extended to other quite radically different contexts. This frequently acknowledged dilemma in which emerging technologies from 'advanced countries' are noted to have negative impacts on the 'developing countries', was also discussed in the original Sussex Manifesto (which termed these 'backwash effects' – see paragraphs 2, 44 and 92). In the early 1980s, Oldham and Kaplinsky discussed the idea of an 'early warning system' to investigate emerging technologies, their potential benefits and future negative impacts. More recently, advocacy groups such as ETC Group have argued for an International Convention on the Evaluation of New Technologies (ICENT) (ETC 2005).

In general, it appears that international institutions that already conduct some form of technology foresight/assessment, in particular those within the UN ambit, have often been slower to respond to the kinds of critiques leveled at TA and TF at a national level. There is, for example, little discernible retreat from highly scientistic practices of risk analysis at the Codex in the way that is beginning to occur in many national jurisdictions. As mentioned, the IPCC also remains primarily a highly technical body. This is perhaps a result of greater insulation from mechanisms of accountability and civic engagement.

More interesting, perhaps, are a few international institutions that have undertaken general assessments involving some kind of extended or interactive technology assessment/foresight-type activity. Even though not always explicitly labelled as such, these present useful models on which further experiment might be based. Arguably foremost amongst these are the Millennium Ecosystem Assessment and the International Assessment for Agricultural Science and Technology for Development (IAASTD). The latter is interesting in that it was an assessment of the future of agricultural science and technology in relation to development, that explicitly aimed to avoid the top-down, Northern-dominated expert assessments of the past, and instead aimed to be more inclusive and participatory in both its design and process. Some 900 people across 110 countries were involved in a multi-stakeholder process involving business, civil society and policy-makers. Scoones (2008) describes how the IAASTD process struggled to maintain a plural inclusive process that genuinely tackled normative and political issues, and that opened up debates and options on agricultural science and technology issues. The tensions proved to be extremely difficult to resolve. For example, between the reflexive ideal of allowing contrasting framings to be debated and different political and value positions to be acknowledged on the one hand, and on the other, that of reaching common understandings and visions for the future, based on the ideal of consensus and an appeal to the objectivity of science and expertise.

AN AGENDA FOR INTERNATIONAL FORESIGHT AND ASSESSMENT?

Technology Foresight has an overtly future-oriented focus, but without a great deal of explicit attention to the relative pros and cons of alternative socio-technical options. Technology Assessment, in examining the potential impacts of proposed technology commitments sometimes looks at strategic options, but it does this without much extension into the future. Combining the merits of both approaches could help to make more explicit the particular contingencies, contexts, conditions or perspectives under which different possible technologies might alternatively be favoured, and the possible implications of those options, in terms of both the nature and distribution of impacts. A number of authors have also argued that foresight/assessment activities can contribute explicitly to the development of adaptive policy strategies that intentionally foster diversity in policy and technological options (Weber 2002). As

such, foresight/assessment activities might serve as an appraisal tool that directly addresses the Manifesto's 3Ds of *direction*, *distribution*, and *diversity*. (See Stirling 2009)

Unless they are formally linked to the existing institutional framework for world trade regulation, international foresight/assessment exercises may be unlikely to involve direct links with resource allocation decisions. However, as Kuhlmann et al (1999) note, foresight-like activities are a way of obtaining opinions, conflicting or otherwise, about future developments and these are capable of creating synthesis, they are disruptive and interfere with current modes of thought, thus forming and shifting values. Such efforts at appraisal can have long-run indirect effects on the priority setting and resource allocation decisions undertaken by a range of public and private actors. Martin and Johnston's analogy of foresight's role in 'wiring up' the innovation system is pertinent here. If foresight/assessment exercises manage to broaden the process and actors involved in such exercises so as to include stakeholders and perspectives that are relatively marginalized in global and national innovation systems, then foresight/assessment might be a mechanism for constructing, framing and articulating development 'needs', and for bringing these to bear on innovation actors.

Yet, as many commentators have argued, foresight/assessment activities are well able to obscure the diversity of perspectives and values extant in society that bear on possible and desirable technological futures. Interestingly, technological controversies - that play out beyond the institutional confines of foresight/assessment exercises - have often been recognized as informal processes of technology assessment (Cambrioso and Limoges 1991). The absence of institutional control has often meant greater scope for articulating alternative framings of what is at stake in technological issues, and often more vigorous and wide-ranging analyses. The challenge is to capture the plurality of perspectives and the energy that often arises in these more informal processes, and to build on the more innovative formal developments at national level that recognize the open-endedness, contingency and capacities for social agency in technology choice. These have attempted to open up appraisal to a broader range of salient bodies of knowledge and disciplines, address uncertainty explicitly and better reflect and bring into appraisal the perspectives and values of a wider range of actors, especially those that are marginalized in existing innovation processes.

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