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# Technology foresight in transition


## ABSTRACT

Technology Foresight (TF) became an increasingly popular approach for science, technology and innovation (STI) policymakers from the mid-1990s on. Achieving prominence in Japan and Western Europe, it attracted the attention of researchers and policy analysts in many parts of the world in subsequent decades. TF is often seen as a set of tools for informing decisions about STI priorities within established innovation systems. These priorities have necessarily changed as scientific knowledge, technological opportunities, and social demands have evolved. But so too have the ways in which innovation processes operate, and understandings of the roles that STI policies can play. Accordingly TF has also been applied to inform efforts to restructure innovation systems - and, indeed, it was often seen as also providing tools to assist in such efforts. The need for such restructuring has been particularly acute in countries undergoing massive transitions. These include transitions from centrally planned to market economies, from non-industrial to newly industrialized countries, and from being imitation-oriented to becoming innovation pioneers. Correspondingly, considerable effort has been put into TF in many such countries. But much of this TF effort has been largely invisible, or at best poorly documented. TF may itself require redesign, taking different forms in various contexts, and as experience with the tools has accumulated. This might involve different patterns of emphasis of, and ways of articulating: the methods that are employed; the stakeholders engaged; the linkages with STI policymaking; and so on. Informed by the contents of this Special Issue, this essay considers the issues arising from this diffusion and evolution of practice, outlining the main capabilities required to mount successful TF exercises in different contexts.


## 1. Introduction

For most of human history, the disruptive changes encountered by even the most complex societies mainly involved tribal and military conflicts, political upheavals and the effects of geological or meteorological shocks. There were few grounds on which to anticipate substantially new economic activities and ways of life, let alone to imagine that these might be underpinned by new scientific knowledge.[1] However, since the scientific and especially the industrial revolution, long-term planning and policymaking have necessarily had to take into account the probability of future technological change.

Disruptive technologies and new forms of work and consumption became increasingly evident with the emergence of the factory system, steam power, and later on electrification and new agricultural, communication and medical technologies drawing on deeper understandings of biology, chemistry, and physics. Creative individuals - often scientists or well-informed science fiction writers like Verne and Wells, and later on Stapledon and many others - produced compelling appraisals of transformative change in the later nineteenth and early twentieth centuries. Demographic and economic forecasting became established practical tools where statistical data and methods could be brought to bear, and there were occasional warnings of resource depletion, such as Jevon's *The Coal Question* in 1865. Systematic approaches to technological forecasting only emerged in the years around the Second World War, as technological progress came to be seen as more of a process of accumulation of knowledge, contributed to by many players, than the product of unpredictable insights from isolated geniuses. (The work of William F. Ogburn and colleagues is important both for this appraisal of the innovation process and for the development of tools for assessing trends and impacts of change.[2]) The development of tools and

[1] Perhaps the agricultural revolution was seen by those caught up in it as involving new knowledge - the story of the forbidden fruit in Eden can be interpreted in this light. We know little of this, since record keeping was largely associated with the tributary systems that arose in agricultural societies. We doubt, though, that this was interpreted as representing a trajectory of progressive change.

[2] See appraisal of Ogburn by Duncan (1968), Godin (2010), Kotsemir et al. (2013), Meissner et al. (2016).

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techniques for technology forecasting was subsequently honed in the context of military and large-scale technoscience projects such as the US space programme. Many of the techniques of technology forecasting (Delphi, scenario analysis, trend analysis, etc.) were adopted to greater or lesser extent as the field of "futures studies" crystallized from the 1960s on.[3]

In the 1970s, Japan institutionalized a system of analysis of opportunities facing national Science, Technology and Innovation (STI). This was initially known as Technology Forecast. Technology frontiers - and ways of reaching them - were of great interest to a country that was, in this decade, moving on from being an imitator of Western innovations. It was becoming a leader in its own right, especially in electronics and related industries. Among other means, the Japanese used tools such as Delphi to aid long-term STI policy-making and generate collective awareness of STI possibilities, and thus to help Japanese industry undertake this transition towards innovative leadership. This experience was to prove influential when Western countries concluded that they had difficulties of their own in STI - many economies were already seen as falling behind the USA, and now Japan and other new contenders were seen as challenges. Similar ambitious TF programmes were developed in Canada and several European countries, in the 1980s and especially the 1990s. The term Technology Foresight was used to describe the large exercises that were being undertaken. (This terminology was then used by the Japanese to label their own exercises.)[4]

A number of factors contributed to the subsequent global spread of TF. International organizations - notably the EU, APEC (particularly influential in South East Asia) and UNIDO (especially in Latin America and Eastern Europe) organized training programmes, held conferences, and produced guides to best practice. The EU effectively required new members in Central and Eastern Europe to use Foresight in developing their own STI policies. Some countries' efforts were half-hearted, or examples of "me too" following of fashion. But policymakers in many countries did recognize that their existing STI policies faced acute problems. Among these were:

- difficulties in assimilating new generations of technology (let alone contributing to them);
- problems in reconciling pressures on public finances with the calls to finance new initiatives in STI (and even to retain longstanding commitments);
- a sense that existing structures for governance of STI were cumbersome and ineffectual (this was especially the case for countries leaving the Soviet bloc);
- social unease about some aspects of science and some applications of technology (notably biosciences and nuclear technology), together with demands for accountability where public expenditure was required;
- new challenges related to energy and food security, climate change, and the like.

While some of the experiences with TF, as it spread from Western Europe to other regions, are well-known, many others are poorly documented. The issues that had to be confronted in implementing the approach have only been discussed to a limited extent, and among specialist groups of practitioners.[5] The essays in this issue of TFSC are intended to help bridge this gap; we are fortunate to have detailed knowledge of a good range of case from informed observers and practitioners. These essays can hardly represent the last word in analysis of the diffusion and evolution of TF, since many other experiences remain relatively underexposed.

The various guides and training programmes to TF that were produced around the turn of the century frequently made the case against "one size fits all" methodology in TF. Whereas some influential consultancies had effectively promoted their "one, true" approach around the world, many TF pioneers insisted that while some general principles were standard, it was essential to design TF exercises in the light of local circumstances. The objectives and scope of the TF, the resources (of expertise and political support as well as funding) that could be drawn on, the participants to engage, and so on, were liable to vary considerably from context to context. While it is fairly straightforward to identify the decisions that need to be taken, the ways in which these are handled will be very contingent on circumstances.

Despite the variety of exercises - differing in focus, scale, and other attributes, common features of most TF exercises can be summarized as follows:

- The TF is designed to have an influence on **policy**, not as an ivory-tower exercise.
  - Thus it is important to have access to influential decision-makers, and ideally they will be engaged as sponsors of the work.
- The influence may be narrowly conceived, for example in terms of identifying priority areas for financing of R & D or training.
  - But TF will also often play a role in addressing weaknesses in the innovation system by helping to align different stakeholders around shared appraisals of future prospects.
- The **products** of an exercise will typically include codified reports, presentations, Internet resources, and the like.
  - Wider outcomes will also involve "process benefits" linking together stakeholders and, not least, enabling key actors to understand why particular policies are being pursued and what their roles could be.
- The TF is liable to be **participatory**, to network together many sources of knowledge in different locations and institutions.
  - The complexity of modern societies and the technologies they employ is such that it is difficult for any individual agency to acquire all knowledge required to take informed decisions in the STI arena. Thus it is necessary to engage stakeholders who have knowledge of, for example, key issues in science, in commercialization and application of inventions, in markets, intellectual property, and trade.
  - Such wide engagement can be important for establishing the legitimacy of decisions informed by the TF.
- Bringing together these different actors and their knowledge may be undertaken through tools such as Delphi, or via more face-to-face methods like conferences and workshops.
  - Sharing and fusion of the different types of knowledge may require more than traditional presentations of different fields of work, and methods such as scenario analysis, "soft systems" and roadmapping can play a role here.
  - The networks and mutual learning established in such work may play important roles in shaping actors' strategies and decisions beyond the immediate focus of a TF.

[3] For accounts of futures studies around the world, before the current wave of TF, see Fowles (1978).
[4] For a fuller treatment of this history, see Georghiou et al. (2008), Miles (2010).
[5] Georghiou et al. (2008) do consider TF activities in various regions - but the level of detail on Central and Eastern Europe, Latin America, and Newly Industrializing Asia, is far from complete.

- The TF is **prospective** by definition, taking a longer-term view than is normal in policy-making.
  - Integrating such perspectives into policy-making requires knowledge of decision timetables and policy language; this is best accomplished through engagement of policymakers and analysts in the TF process.
  - The case will need to be made for the value of incorporating long-term costs and benefits into immediate decisions and actions. The anticipated outcomes may well not emerge until after current politicians and other actors have long gone. But their names may live on as heroes or villains, and they may care about their children, grandchildren, and communities - or be under pressure from those who do.

These features will be realized in different ways, reflecting the different contexts within which TF exercises are initiated. It has been common - and we would argue that it is good practice - to precede a TF exercise in one country or region with a review of what has been accomplished elsewhere. Over time, too, there is likely to be learning about what works most effectively in local contexts across a series of exercises (Meissner, 2012). There may be learning from activities undertaken by corporations or other influential actors, or from more limited activities such as a smaller-scale modeling or roadmapping study. It may well be that pre-existing futures studies in the country/region in question, the communities of researchers that have contributed to them, and the reception that they encountered, will also have an influence. Capabilities to mobilize and learn from knowledge about TF predecessors are among the conditions necessary for conducting effective TF.

## 2. Foresight: constituencies and capabilities

What else can experience tell us about TF capabilities? While the need to adapt methodology to specific settings has been stressed, we can still see the application of similar methods across most TF exercises. This presumably reflects the tendency to model an exercise on what has been done in other countries, and what is reportedly most successful in such cases. There is probably also some influence from consultants drawing on their own experience, or even promoting their own preferred tools.

It is difficult to accurately assess the uptake of methods. Some efforts have been made to compile relevant information. But these are not very consistent in their definition of what constitute TF exercises, nor in their classification and demarcation of various methods. For example, there are numerous varieties of both Delphi and scenario analysis, which may be used for different purposes and in different stages of a TF process. Simply knowing that an exercise used a Delphi or even a scenario workshop tells us little about the precise form this instrument took, and how it fits into the overall exercise.

One effort to “map” Foresight around the world was the European Foresight Monitoring Project (EFMN - later succeeded by the European Foresight Platform).[6] Summarizing its results, Popper (2009, p13) concluded that

> “some methods are very widely used across the world; such is the case with expert panels, literature review, scenarios and trend extrapolation. But the more interesting findings are those that can tell us more about differences in regional foresight practices. The first of these methods is (futures) workshops, which figure notably in Europe and North America, but are much less important in Asia and Oceania and are out of the top ten in Latin America. The second method of interest is the Delphi technique, which is most often used in Latin America, Asia and Europe, but is absent from the top ten in North America. Finally, it may be useful to look at the average number of methods used by each region: International (4), Europe (5), Latin America (8), North America (4), Asia (4), and Oceania (3).”

Of course, it is not surprising that a TF exercise will almost invariably involve an expert group, make use of a review of literature on the topics in hand, and consider the trends evident in the domain being addressed. (Presumably it will also undertake more or less extensive “horizon scanning” to also review prospects that may represent a break with existing trends). Since scenarios may take various forms, including single-scenario analysis (e.g. a desirable future, or a worse-case that is to be avoided, alongside several varieties of multiple scenario analysis), the prevalence of this approach is to be expected (Miles et al., 2016). (Indeed, many commentators argue that a key feature of TF is the recognition of the fluid nature of the future, and the consequent value of exploring alternative futures.) To some extent, the examples set by well-publicized TF efforts may also help consolidate expectations that particular methods will feature in a serious TF activity.

Explaining the regional variations may be more problematic. The EFMN report does not tell us **why** particular methods were chosen. Speculatively, workshops are easier to mount in smaller countries, or those with well-developed transport infrastructures; while Delphi may be a preferable method of accumulating expert views where this is not the case. (For example, Hilbert et al. (2009), report that a Delphi approach was the only feasible way of interacting with a large expert community scattered across Latin America and the Caribbean.)

Popper also argues that we are likely to see face-to-face workshops used in societies where open debate is fostered. In contexts where authority relations are such that deference to older and more senior colleagues may prevent public expression of dissent the anonymity and quantifiable output of Delphi may be more attractive. We might also expect that in contexts where material presented in numerical form is particularly valued (e.g. for the objective that the EFMN describes as government “orchestrating socio-economic activity”), its quantifiable output is attractive, which would also be the case for tools such as trend extrapolation, computer modeling and cross-impact methods.

As already mentioned, a method may be implemented in very different ways depending on the objectives and contexts involved. For example, Hilbert et al. (2009) used online methods to conduct a policy Delphi, rather than the more common sort of exploratory Delphi. Anecdotal accounts tell us that one example of an exploratory Delphi in a Middle Eastern country involved experts being called to a meeting by a member of the local ruling family, and then made to complete the questionnaire on the spot. Where in the various stages of a TF process the method is located also implies that it is drawing on different sets of prior knowledge and being applied to different functions.

Approaches also evolve alongside the development of new technical facilities - such as online capabilities permitting website surveys, collective modeling efforts, rapid dissemination of draft and final reports, and so on. Capabilities to implement such methods, too, vary over different places and times.

The EFMN reported that most exercises captured in its dataset were conducted at national level, with government policymakers the main target audience. Corporate TF exercises are probably underrepresented in the set of cases mapped, both because they will more often be subject to commercial confidentiality, and because their participants may have less reason to publicize them than do academics and consultants. However, such

[6] Information on these projects, which unfortunately no longer seem to be continuing, can be accessed at http://tinyurl.com/jnprrvf and http://www.foresight-platform.eu/ (accessed 1/12/2016).

corporate efforts are liable to be small-scale and restrictive in terms of range of participants. There are exceptions: some corporate work is designed for wide circulation. Sometimes cities and regions have initiated large-scale exercises. But the bigger exercises, and those that get embedded in STI policy, are liable to be most often ones that are funded or supported by national governments.

The EFMN report did not explore regional variations in the objectives of TF, but does note some variations in the typical outputs. *Policy recommendations*, as we would expect from the target audience, are most frequent in all regions, especially Europe, Latin America and Oceania. *Analysis of trends and drivers* is relatively more frequent in Latin America, followed by Europe. *Scenarios* are less frequent in North America and Asia. *Research and other priorities* are relatively more frequent in Latin America and Oceania, followed by North America. In contrast, *Key technologies* (the identification of which is likely to be a precursor to priorities being established, but perhaps these are debated and established outside of the TF), and *Forecasts* (possibly drawing attention to developments elsewhere that will need to be taken into account, and quite likely to be in quantitative form) are more prominent in Asia than elsewhere. *Technology roadmaps* are most prevalent in North America, and do not feature in Latin America. The latter result might be indicative of a country (or those sectors of its economy involved in the TF exercise) being closer to the technology frontier. Or it might be related to US exercises being designed to align a multiplicity of relatively independent private sector actors. Some of the other regional variations are hard to interpret. It may be that the data involved are just too noisy - the EFMN survey sample and classification of methods have already been mentioned, but the judgemental process involved may also introduce errors. The main implication of this brief review is that we need considerably more detail on individual cases, and how these are located in different country contexts. Historically-informed case studies are vital, even if they may prove harder to analyse statistically.

When we turn to individual cases, a much richer picture is liable to come into focus. Consider for example the Colombian exercise, reported in a detailed evaluation[7] by Popper et al. (2010). Here was a country where it was decided that a major part of the TF programme should consist of establishing horizon scanning capabilities (vigilancia) in specific major sectors of the economy. Dozens of capacity building courses were run, involving more than 3000 participants. Instead of focusing on an effort to set priorities for STI for the whole economy, the aim was to enable key actors in the innovation system to better appraise, and better work together to appraise, technological opportunities for the country. It linked together numerous research groups (centres of excellence, university groups, government agencies and ministries, technology development and productivity centres, public enterprises and others. Sectoral and thematic research projects and strategic studies to reorient public-private instruments were undertaken, and support given to specific lines of research in STI Programmes. This is quite distinctive, as compared to the typical TF Programme as established in Western Europe.

Most accounts of TF Programmes (TFPs) have been content to describe how the exercise was constructed, what methods were employed, and what the main outputs were. Most of the published accounts, furthermore, deal with Programmes that are regarded as successful, since problematic cases are much less likely to be publicized. Given this, it is not remarkable that the outputs of the cases that have been well-publicized were taken seriously by sponsors and other stakeholders. Moving away from success stories, we can understand the development of TFPs as in Fig. 1. It illustrates the point that the design of TF will depend on features of the local context, which are also liable to shape both its implementation and its impacts, each of which will be shaped by the resources deployed and the engagement of stakeholders.

Emerging and transition countries are liable to demonstrate rapid change in the governance structures of their innovation systems. This goes along with frequent restructuring of governmental institutions and agencies, and with the respective adjustment of duties and responsibilities of them. This can also mean a higher turnover of their central staff and leadership. Similarly, industry and services may well change staff more frequently than do comparable entities in the developed economies. These factors can have positive consequences in terms of infusing new approaches (and disrupting old cliques), but create challenges for the conduct of TF and the implementation of recommendations arising from its results.

### 2.1. The contents of this Special Issue

The essays that follow in this Special Issue illustrate the diversity of TF experience around the world. They display that there have been huge differences in the scale, institutionalization, and focus of activities, as well as in the precise configuration of methods employed. But these essays also illuminate the common features that are apparent in tailoring the practice to the circumstances of countries undergoing major transitions. These transitions may result from - and contribute to - political change, more or less rapid economic development, and/or other factors. (We can anticipate that climate change will register as an important factor in coming decades, and one that may render the lessons derived from these experiences relevant to a great many countries.) In the next paragraphs, we note distinctive features of each essay, and what they have to tell us about capabilities required for successful TF, since many of the conclusions derived from each essay are more general relevance than the particular cases they consider.

We begin with some overviews of practice. First, David Feige and Nicholas Vonortas (2016) recognize that while TF has been increasingly undertaken by developing countries in order to assess technology platforms for future growth, in many cases the TFPs have failed to exert much influence on policy decisions. Why should this be? Three factors for enhancing policy relevance are discussed, indicative of three shortcomings in many TFPs. First, foresight activities would benefit from being more informed by reflections on the experience of, global convergence over the past few decades. Relevant lessons could be drawn as to how to organically incorporate such concepts as *absorptive capacity* and understanding of *technology gaps* into TF exercises. (Each of these requires analytic capabilities, of course.) For example, it may be more relevant to examine the scope for mastering established technologies than to explore options for working at technology frontiers (especially not in every major technology domain). Second, while TF may help “wire up” a poorly articulated innovation system, this is not the same as creating such a system from scratch. The more components of a functional national innovation system there are, the greater the likelihood that a TFP will be effective. As suggested, these are liable to include capabilities to acquire and employ existing technologies in effective ways. Third, developing countries are advised to consult widely in the foresight process, and not just rely on narrow expertise. As well as moving the focus beyond one just featuring specialized (and typically highly technical) aspects of the domain being addressed, broader engagement can help the achievement of wider buy-in, and promote more sustainable initiatives. This practice has underpinned the more successful TFPs in the industrialized world.

Allan Dahl Andersen and Per D Andersen (2016), build on the systems of innovation approach, and draw particularly on cases from specific exercises and institutions in Brazil (the ARDI/CGEE Plano Estratégico Setorial) and South Korea (the Korean Institute for Advancement of

[7] Incidentally, the evaluation exercise involved much consultation with stakeholders and several public presentations, thus serving to further disseminate knowledge of the exercise and its results.

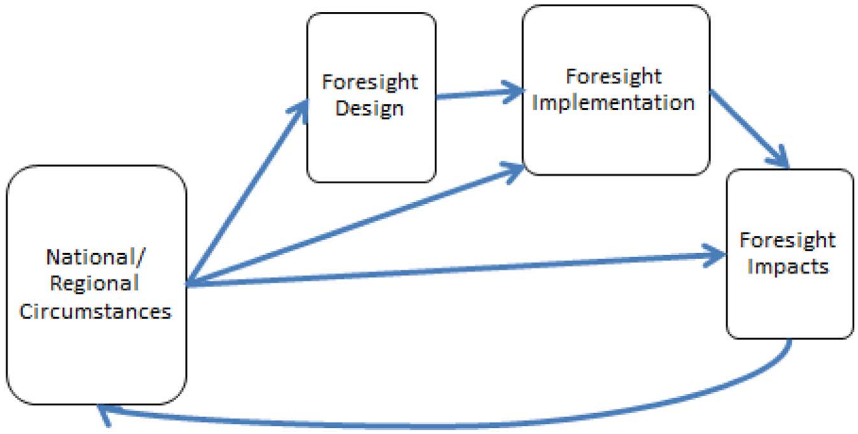


**Fig. 1.** Technology foresight in context.

Technology's roadmapping and TF activities, in particular). It is interesting to contrast their graphical representation of dynamics than our less elaborated Fig. 1. They further develop the case for TFPs, and innovation system policies and policymaking more generally, to be inclusive. They argue that while TF needs to be inclusive in the sense of broad stakeholder participation: it should also take into account what is now known as inclusive innovation. They argue that "Innovation Systems Foresight" can be a driver for more holistic STI policymaking. This engages a broader range of actors at different levels within a national innovation system, going beyond governmental agencies (important though these are as sponsors of, participants in, and targets of the exercise). Diffusion of innovation is important, alongside the creation of bright ideas and new technologies. This requires the willingness of key stakeholders to accept change - and so policymaking needs to consider the variety of stakeholders and their interests, in order to contribute to shaping innovations, preparing the ground for accepting change, and enhancing the diffusion of innovation. Features of the Brazilian case are discussed that supported the development of more inclusion-relevant capabilities than in the Korean case: these include innovation system features and more general political orientation. Eventually, the authors argue, such greater inclusiveness should lead to more elaborated styles of TF. Alongside the notion of inclusive innovation, we would suggest that what is sometimes known as "responsible" or "sustainable innovation" needs to be considered.

A second set of papers focus more on the experiences with TF of individual countries, though, as discussed already, these experiences have often begun with the emulation of some of the practices observed in other countries.

We begin with several that concern experiences in countries that are large, undertaking rapid (often high-tech) technological development, or are both. Sang-Jin Ahn (2016) analyses South Korea's TF practice, again discussing this in relation to the national innovation system and broader STI policy practices, and arguing for engagement of nongovernmental actors in the TFP. The country has experienced a "research boom" as R & D investment has grown substantially - along with the economy moving beyond catch-up to being a major player at the technology frontier in many fields. Ahn examines how TF was established as an institutional framework aiming at enhancing the national innovation competences in South Korea, with the goal of bringing the country closer to the leading edge in innovation. TF has been just part of a range of activities intended to bring long-term perspectives to the fore. The Korean approach to TF goes well beyond basic technology forecasting, but Ahn notes its limitations for the Primary Feasibility Studies (including both economic and policy analyses of costs and benefits over time) that are required for large-scale R & D programmes. The coherence between TF and STI policy involves applying a "value chain logic" achieved by using foresight at each decision point - "one-time national foresight" does not provide the detail required for the quantitative ex ante evaluation of options that enables support to be given to these large funding decisions. Capabilities to mobilize evidence, at the level of detail and in a form that fits national decision-making practices, are thus required for TF to inform policymaking.

While China is outstanding both in scale and speed of industrialization and catch-up, and a significant number of TF exercises have been conducted in China in the recent past, these efforts have had little thorough discussion in English-language literature. Na Li, Kaihua Chen, and Mingting Kou (2016) in their contribution, outline (and place into international context), trends in publications and practices concerning TF in China since the 1990s. "Critical Technologies" approaches were dominant early, and continue to be of importance, but have been complemented with Delphi and scenario methods, along with other tools such as bibliometric and patent analyses. The results of such Chinese TF activities are regularly used for STI development and planning by national government and agencies (and by regional actors and cities such as Beijing and Shanghai). Chinese TF exercises typically place strong emphasis on the active involvement of a wide range of stakeholders. Indeed, their aim is frequently explicitly that of fostering and enhancing stakeholder communication, partly in order to embed a TF culture across many parts of the huge and diverse economy, and the complex and multi-level policy systems that characterize China. As well as the technical capabilities apparent in the numerous studies that are described in this essay, it is evident that it is critical to possess capabilities for engaging stakeholders and articulating the process and results of TFPs in ways that are meaningful and motivating - for a large number of actors, in a country undergoing rapid change. The authors also make the case that further development of TF techniques will be an important issue to attend to.

Turning to another large country, Leonid Gokhberg and Alexander Sokolov (2016) discuss the interesting case of the evolution of strategic long-term STI policy in Russia, looking at developments over almost a hundred years. Summarizing and perhaps simplifying their account, we begin with basic technology forecasting as might befit a centrally planned industrializing economy. While forecasting necessarily continues to play a role, the move has been towards TF as a fully-fledged anticipatory policy making tool; this implies recognition that the major role of government in shaping STI evolution is situated in a complex economy and society in which knowledge, agency and capability is widely (if far from equally) spread. Even before recent developments, Russia led the way in some planning tools, such as pioneering TRIZ. As in the case of China (and, in its own way, South Korea), there have been numerous efforts to bring long-term analysis to bear on immediate decisions about funding of research and other innovation activities. This has been in a context where the STI performance of the country, with the exception of a few areas, has lagged behind expectations. Priority areas for development have been determined, with tools like Delphi also being used to assess the relative standing of Russian R & D in various fields. Thus national frames of reference have been established and renewed, in terms of appraisals of prospects for major sectors and technologies. TF has been related to innovation system analysis and to the exigencies of translating systematic analysis into implemented policies. Furthermore, there is also more recently effort to create networks of expertise in TF that can work effectively together so as to coordinate initiatives at various levels and in various sectors. The development of capabilities for TF is explicitly recognized, and thus capabilities to train TF practitioners and diffuse understanding of approaches and rationales are developed, as is further outlined in the subsequent essay.

Oleg Ena, Alexander A. Chulok, and Sergey A. Shashnov (2016) delve more deeply into the role of networking, and the processes of network-building, as they have emerged in the Russian context. A set of Industrial/Sectoral Foresight Centres have been established, in various locations across the country, with efforts made to integrate these into national and regional innovation systems - not least by surveys exploring the demand for the TF services they could provide, and efforts to integrate TF with elements of STI policy such as support for clusters and for technology platforms. Several hundred organizations and over a thousand experts are effectively networked together, with training and other capabilities put into place. Initial configuration of the network was based on an analysis of good practice around the world, framed in innovation system terms; and stress is placed on the monitoring of network performance so as to allow for renewal of key players, standardization of outputs, and assessment of outcomes. This indicates the importance of organizational and managerial capabilities in the TF mix.

TFPs are not restricted to countries that are already highly industrialized, and these analyses need not be applied to manufacturing and related sectors alone. TF (and Foresight more generally) for service and agricultural industries, for infrastructure, and even for voluntary organizations, is not unknown in Western Europe and the USA, for example. Several papers in this Special Issue consider the cases of developing countries, whose experience with TF is typically more recent, and where capabilities may require more nurturance.

Mauricio Cespedes Quiroga and Dominique Philippe Martin (2016) look at TF in a low-income country, and in a sector often regarded as backward. The Bolivian TF they describe, an exercise sponsored by UNIDO, was very much a learning experience for participants: and offers rare insights into how TF might address such a country's marginalized sectors (in this case, medicinal plants and textiles based on a natural fibre). They make the case that a vicious circle, rooted in a misfit between institutions in the socio-technical regime, characterizes these sectors' innovation efforts. Sectoral TF, the authors argue, needs to take into account the overall value chain (and possible future value chains) that the sector involves. These include, among others, producers/collectors (who may be in the informal economy), and industrial processors, of the "raw materials", and traders and exporters of various kinds. Location within value chains which may be very sector-specific, is liable to influence on the one hand economic and technological development, and on the other hand the pattern of winners and losers that are associated with these. Capabilities to relate R & D and other innovation support activities - on the part of Universities, government agencies, and other parties - to the circumstances of actors at different points in value chains, are required. Politicians who aim to support vulnerable rural communities will need these capabilities, as well as the ability to influence other parts of the innovation system accordingly. The need to be able to examine complex value chains, and not just individual links in such chains, is a general point emerging from several of the essays in this Special Issue. Furthermore, it is a point that applies to efforts to establish high-tech industries just as much as to traditional economic activities. An example of this would be the dilemma faced by Taiwan, whose industrialization has been very much a matter of securing status as an OEM (Other Equipment Manufacturer) for global corporations based elsewhere - this may be associated with another sort of vulnerability!

The third set of papers looks at the environment to apply TF from country perspective. Maribel Guerrero and David Urbano (2016) discuss the role of government in the innovation system and how triple helix elements are involved in the transition of the innovation system thereby showing the framework under which TF is applied and which it impacts potentially. They use the case of Mexico which is a populous middle-income country, which has displayed fairly impressive economic growth over recent years - despite well-publicized problems with crime and political conflict- but whether this can be sustained given current political and trade problems with the neighboring United States is a source of concern. Finally, David Botchie, David Sarpong, and Jianxiang Bi (2016) again raise issues to do with inclusive innovation and global value chains, looking at another low-income country. In this case, the Ugandan garment industry is the focus of attention. The research - undertaken as part of the inputs to a TF exercise - examines how far sewing machines from "Northern" versus Chinese manufacturers contribute to the economic success of (mainly poor, rural, female) garment producers. The TF activities would need to take into account the conclusions in appraising options for further development of the sector. The study indicates that the less sophisticated but lower cost Chinese machines offer the better prospects (despite many issues with break-downs and repair), and explaining what factors underlie this; in other words, the TF is to be informed by the application of capabilities in conducting research into the organization and practice of a small-scale industry, and one that faces tough foreign competition. One interesting reflection on the part of the authors is that this may signify a shift in how we envisage "appropriate technologies", away from their being the result of initiatives from international and not-for-profit organizations, to being driven by technological solutions that emerging economies such as China (and India) promoted for internal reasons in the first instance, and are now and exporting in response to rapid growth in demand from low-income consumers. (We are reminded of discussions of "bottom of the pyramid" innovation.)

There are many specific points made in these essays, and we pick up some of these in the following discussion. What is a common thread is the need for TF to extend beyond the purely technological, and to pay serious heed to organizational issues. The organization of TF itself is part of this, with new institutional structures and networks being often mentioned as at least a facilitating factor, and quite possibly a precondition, for success (in the sense of seeing results of TF put into practice). But also organizational issues arise in the development and diffusion of technologies and technological capabilities, and in the location of economic activities in value chains wider than sectoral and national contexts. Without attending to such features of innovation systems it may be that the analyses and the implementation of results remains far from optimal.

## 3. Conclusions: constituencies and capabilities

How can we analyse these features of TFPs as outlined above - and, again, how can we identify the capabilities required for these programmes to be successful? Let us step away from the essays we have just reviewed, for a moment. Systematic ways of understanding the emergence and effectiveness of STI programmes have been developed that can be applied to TFPs. Actor-Network Theory is probably the best known of these approaches (cf. Latour, 2005). The socio-technical constituency approach of Alfonso Molina (1992,1997) is particularly relevant, since it was designed to help understand the factors that make for successful or unsuccessful development and implementation of such programmes, and in some recent formulations it has been related to innovation systems approaches (cf. López-Martínez and Piccaluga, 2000).

The approach examines the "dynamic ensembles of technical constituents and social constituents which interact and shape each other in the course of the creation, production and diffusion of specific technologies" (Molina, 1992: 483) By *technical constituents*, Molina refers to the tools, machines and hardware involved in the development of the technology; by *social constituents*, he refers to the people, firms and the institutions involved in the development of the technology. Molina stressed "technologies" in his initial work, in part to demonstrate that the evolution of particular artefacts (microprocessors in his case) was contingent on social factors as well as technical opportunities. In practice, much of the research using this approach has focused not on specific technological artefacts, but on STI programmes involving technology development (such as the European programmes aimed at microprocessor and then more general development of Information Technologies).

The effort to integrate the technical and social aspects of technology development (or of an innovation programme) has meant that the socio-technical constituency approach has been applied at both product and industry levels, as well as having been used in the effort to explore national innovation systems. A key point of the approach is that there needs to be *alignment* between a number of factors for the STI programme to be successful - and this can be argued for TFPs, too. First, the programme must be realistic, to have achievable objectives (or at least, to be able to achieve enough to satisfy stakeholders). In the case of a technological project, this might mean that the artefact can be constructed within the cost and time parameters specified, and accomplish the task required for it. An STI programme - or a TF exercise - similarly will need to be able to effect change in, for example, the technical and commercialization capabilities that have been identified as critical for the innovation system. At the outset, stakeholders need to have a persuasive case made that the programme can achieve its ends; and its ultimate success in doing so will depend upon how well the programme design was able to accomplish this.

The resources (human, financial, material, time and space resources) committed to the programme need to be adequate - which requires mobilization of institutions providing these resources. These institutions (financiers, for example, who may be firms or government agencies; sources of expertise like Universities, and so on) also need to be aligned. They must have at least some common interests in the programme's viability and success. The social constituents thus shape the development of the programme, through the control they exert over resources. Of course, some stakeholders will be more influential than others in this regard, given that command over financial, intellectual and political resources being unevenly (and in complex societies, widely) distributed.[8] Stakeholders may include, for example, policymakers, firms, Universities, and the public at large; and each of these groups may be composed of numerous subgroups with varying perceptions and interests.

This approach allows us to view TF programmes as interactive processes, in which social and technical constituents are closely interrelated in shaping the path of development and eventual success or failure.[9] Alignment between stakeholders - who may well hold different interests, visions, and goals - determines the Programme's development, and thus the extent of success or failure achieved. Relevant resources have to be mobilized and directed towards the same ends. This means that the stakeholders will typically be persuaded of the benefits to them of the potential achievements of the Programme. At least some elements of a common understanding of the Programme that they can agree upon must be established, so that resource flows are coordinated, stakeholders and institutions can work with each other as required. In addition to how well the stakeholders' perceptions and interests are aligned, the extent of success or failure of the exercise is also affected by the design of the TF exercise. The issue here is how well the Programme itself is aligned with the problem(s) it is meant to be addressing, and how specific tools were chosen, deployed, and integrated to achieve this.

This discussion, together with the lessons drawn in the essays of this Special Issue, helps us to identify the capacities necessary for a successful TF Programme, as represented in Table 1. Deficits in these capabilities may underlie serious shortcomings in terms of producing quality results from the work, and/or achieving impact from these results. The TF experiences of economies undergoing significant transitions are likely to be particularly interesting from this perspective, given the possibility for STI policy to play a significant role in the shaping of change.

The cases illustrated in this Special Issue clearly demonstrate that if TF is to extend its relevance, especially in emerging economies, practitioners will need to take a broader view. To become an effective policy making instrument TF exercises need to look beyond the research and technology domains alone, to consider domestic competences and capabilities; breaking away from sector-specific frameworks, to take into account the overall value chain in which sectors may contribute and be affected by impacts and spillovers in all directions.

In cases where TF has failed to achieve many of its objectives, the exercise may have been narrowed to identifying and setting priorities with immediate relevance to STI, while neglecting wider but related societal and environmental developments (Georghiou 2013). Objectives associated with wider features of the national innovation system (redesigning institutions and building absorptive capacity as part of a process of transition - including the move from catch-up to leadership) should be reflected prominently in the design of TF.

In addition, to be impactful TF needs to take into account the ambitions and capabilities of a broad range of actors, across different levels of the innovation system. This is an issue for almost every TF exercise, of course, but it is one with special relevance for emerging and transition countries, which feature ongoing rapid change in many parts of their institutional environments and socio economic regimes. Where there is great uncertainty concerning the future trajectories of the country, TF can be among the ways in which dialogue can be fostered as to long-term outcomes, as opposed to more immediate sectional interests.

Countries undergoing transition can learn from each other's TF experiences, about the conduct of TF and its integration into other STI policy initiatives. Exchange of information, training activities, and results that have significance beyond the immediate national or regional context, can involve conferences and workshops. No doubt there is also scope for joint projects of various kinds, especially when common challenges are being confronted (including challenges associated with new disruptive technologies), or “background information” is being produced (such as “state of the science” reviews, mapping of technology frontiers, modeling of climate change impacts). There may well be limits to cooperation, especially when countries are competing for similar positions in specific value chains. But there is much to gain from deepening knowledge sharing in TF across transition economies, in addition to the usual flows from the industrial world to other regions. This may lead to distinctive forms of TF emerging, reflecting the role of TF in transition processes. TF itself may be in transition, facilitated by the exchange of experience across economies in transition. Hopefully the documentation of experience represented by the following essays will prove to be a weak signal of an emerging trend towards such exchange.

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[8] Just because it is likely that a TFP will reflect such uneven distribution of resources does not mean that it is condemned to reinforce these. It is possible to aim for more inclusive representation, for procedures that give voice to those who would otherwise be silenced, and to promote recommendations that challenge inequities. Procedure such as citizen juries and science courts have demonstrated how STI decisions can be made more open,

[9] The socio-technical constituency approach can be used to examine the whole TF Programme. It can also be employed to give insight into the shaping and performance of specific elements of the Programme (given that most STI Programmes comprise a portfolio of different projects). It can, furthermore, be used to examine the relation of different Programmes and socio-technical constituencies that may overlap or exist alongside each other, and even compete for resources.

**Table 1**
Capabilities required for successful technology foresight.

| Capability required | Tasks involved | Skill sets | Knowledge bases |
|---|---|---|---|
| Managerial | • Scoping exercise.<br>• Keeping participants on task, keeping activities on track and on time.<br>• Promoting efficiency and effectiveness of activities. | • Project management skills.<br>• Effective and persuasive communications. | • Knowledge of key organizations, of cultural practices, of potential power relations and conflicts of interest across various stakeholders. |
| Expertise in domain and beyond | • Ability to identify key players, issues and concepts in domains considered.<br>• Ability to identify and examine critical social and organizational issues extending beyond purely scientific and technological aspects of domain. | • Scanning and selecting among sources of expertise, deploying own (generalist) expertise, and utilizing terminologies relevant to domain experts and experts in related social and organizational fields. | • More than rudimentary knowledge of domain of exercise, its evolution, and key contextual factors impinging on it over long term (including social and organizational issues and global trends and relations). |
| Foresight techniques | • Ability to draw lessons from previous TF experience, to select and implement methods from the TF toolkit, and to integrate results. | • Ability to apply techniques to long-term appraisal of domain and its context, or to manage practitioners applying these. | • Knowledge of application and assessment of Foresight tools and techniques, of their uses and limitations. |
| Social practice | • Identification, mobilization and coordination of key stakeholders | • Social and leadership skills, including persuasion, encouragement, conflict resolution, and management of small and large groups. | • Knowledge of stakeholder management analysis, and of techniques of groupwork and participatory decision making. |
| Policy relatedness | • Successful communication of ongoing activity and results, promoting action based on these. | • Presentation skills, ability to identify and influence key policy levers and change agents. | • Knowledge of policymakers' language and timetables, of existing initiatives and windows for change. |

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