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The role of foresight in shaping the next production revolution

Attila Havas, K. Matthias Weber

Abstract

Foresight can be a highly useful tool to address the opportunities and challenges triggered by the next production revolution. As shown by the various country cases considered in this chapter, it facilitates debating and systemic thinking about multiple futures and helps shaping the future through the process of participation and engagement. Given its participatory nature, key actors are mobilised to form shared views about the future, negotiate their future stakes and interests, and agree on actions aligned to their shared vision. The next production revolution requires quick and proactive policy-making, as well as better orchestration across different policy domains. Foresight can assist policy-makers by providing foundations for robust policies, fostering new framing of policy issues, as well as translating long-term concerns into aligned policy priorities. Furthermore, policy implementation is likely to be faster and more effective when key stakeholders are involved early on in shaping these policies. Foresight benefits, however, are far from being automatic: the chapter considers eight factors critical to achieving those. An astute embedding of a foresight process into policy-making enhances the likelihood of impact, but foresight recommendations are no substitute for policy decisions and actions.

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1 Introduction[1]

Day-to-day decisions, taken either by policy-makers or the leaders of various private and societal organisations, guided by long-term, strategic thinking tend to lead to more targeted – ideally also more favourable – outcomes than *ad hoc* decisions. While there are a variety of approaches to strategic thinking, those that rely on foresight tend to be more robust because they cover a broad spectrum of possible long-term futures as inputs to strategy development. This applies *a fortiori* to those decisions that seek to position a country, a region or a firm amidst the turbulence caused by the next production revolution.

Of various types of prospective analyses, this chapter focuses on foresight because this is a particularly relevant policy approach to address the opportunities and challenges triggered by the next production revolution: besides facilitating debate and systemic thinking about possible futures, foresight also helps shape the future. A well-designed and conducted foresight process identifies and assesses in a systematic and transparent way those societal, technological, economic, environmental, and policy factors and trends that are likely to affect competitiveness, wealth creation and quality of life. Such analysis can be used by policy-makers as inputs for issue definition, as well as for designing policies. It can help turn long-term concerns into urgent policy priorities. At the same time, foresight can raise awareness and understanding of such factors among the stakeholders involved in the process, mobilising them to act and preparing the ground for complementary actions and strategies. In this way, foresight can contribute to the emergence of more coherent expectations and strategies, making policy implementation more effective. By exploring multiple futures (as opposed to a single future) and by bringing together

1 We are grateful for the guidance provided by Michael Keenan and Alistair Nolan when designing the structure of this chapter, as well as for the constructive and thorough comments and suggestions to improve the first draft.

major stakeholders with diverse backgrounds, foresight can help decision-makers cope with an uncertain future and provide the foundations for more robust policy-making.

This is highly pertinent in the context of the next production revolution. The fast and interconnected changes in technologies, materials, processes and business models have major implications for the strategies of many different types of innovation and societal actor. There is a strong need for co-ordination among these actors in order, for instance, to set standards for interoperability, security and privacy, or to develop appropriate curricula and education methods for skills development. These are just a few of the necessary actions to prepare for the future opportunities and challenges of the next production revolution.

To reap the benefits of foresight, policy needs to be receptive to the processes that foresight requires and its policy implications. Ideally, foresight should be institutionalised, with regular rounds of foresight supported by continuous horizon scanning. A fundamental condition for achieving impact is to have a committed policy client. Foresight should be embedded in the decision-making system. A suitable choice of timing, relevance to major policy issues, and co-ordination with other policy initiatives are all critical. It is also crucial to find an organisational set-up that eases the inherent contradiction between the need for foresight work to be close to decision-making processes (to achieve impact), and the need to maintain intellectual autonomy (to generate original ideas and out-of-the-box thinking). Any solution to this perennial tension can only be context-specific.

The next section briefly reviews the most important types of prospective analysis and their policy relevance in the context of the next production revolution. The potential benefits of foresight and its roles in shaping policies are then discussed, again in comparison with other types of forward-looking analysis. Before summarising the main policy and organisational lessons, several factors are highlighted to help policy-makers maximise the benefits of foresight.

2 Foresight and its policy relevance

2.1 Locating foresight among prospective analytical tools

Prospective analyses can be conducted in various forms and pursue different purposes. The best-known forms include forecasting, critical (or key) technologies exercises, foresight, strategic planning in the private sector and indicative national planning. This chapter focuses on foresight, but to better understand its policy relevance – what can and cannot be expected from foresight – it is worth briefly juxtaposing foresight with other types of prospective analysis, in particular forecasting and expert-based (non-participatory) prospective analysis. First, two fundamentally different systematic approaches to the future are considered: forecasting and foresight.[2] Forecasters assume that the future is essentially determined by fairly stable structural and institutional settings, the main features of which can be called driving forces. The main task is thus to identify these driving forces, devise a reliable quantitative model, collect the relevant data and run simulations to generate future extrapolations at given points in time. Experts need to be involved in developing these future extrapolations, which may differ from each other quantitatively, but not structurally (that is, the same variables are used throughout, even if their values change from forecast to forecast). Forecasting can be used either for pure academic exercises or as a decision-preparatory tool both in the public and private sector.

Foresight processes, in contrast, are based on the assumption that the future can be shaped by deliberate present-day actions: at least some unfavourable trends can be altered (redirected, slowed down, or stopped altogether) to some extent and new, desirable ones can be set in motion as a result of private and public actions. Foresight, therefore, explores different possible

[2] Major differences of foresight and expert-based (non-participatory) prospective analysis in relation to tackling next production revolution issues are discussed in the next section (2.2).

futures. In uncertain times, thinking in terms of multiple futures is a necessary precondition for devising strategies to cope with unexpected developments.

To realise foresight's potential to shape the future, major stakeholders need to be involved not only to identify, but also to assess, the major (current, emerging and future) trends, consider a set of feasible futures, and select the most favourable one. In this way, values and interests play a decisive role in foresight processes, and thus it is crucial to make the entire process inclusive and transparent. With the help of participatory methods, foresight can incorporate different perspectives when exploring possible futures and bring to the fore a range of relevant influences and impacts of the issues in question. The process itself can have systemic impacts: due to intense dialogue, existing networks of major actors are likely to be strengthened, new ones created, a future-oriented way of thinking reinforced. The novel, participatory methods also reshape the overall decision-making culture in the affected policy domain.

Furthermore, most foresight activities aim at achieving a common understanding of what a desirable future might be. Such visions and – associated with them – more operational roadmaps can be powerful instruments to assemble different key players around a shared agenda. The main benefit of such visions, roadmaps and strategic agendas is that they help reduce uncertainty about the ambitions of partners and competitors, and thus assist long-term decision-making. Moreover, once participants arrive at a shared vision, they can expect that most of their fellow participants will take steps to achieve that chosen future state, and thus align their future actions to the jointly identified favourable future.

Foresight needs to be clearly distinguished from the strategies it is supposed to feed. In the context of the next production revolution, the German Industrie 4.0 initiative may serve as an example of a strategy, which was inspired at least partly by prior foresight activities in Germany.

The next production revolution is likely to trigger *complex changes* given the interactions of *new technologies* (such as 3D printing and scanning, the Internet of Things, machine-to-machine (M2M) and person-to-machine (P2M) communications and interactions, and advanced robotics); *new materials* (in particular bio- and nano-based materials); *new processes* (for example, data-driven production, artificial intelligence and synthetic biology); as well as *new business models* (exploiting mass customisation, sharing and the platform economy, and servitisation of manufacturing) (OECD, 2016a, 2016b). These changes would affect research, technological development and innovation activities (direction of search, allocation of funds, commercialisation, ethical concerns); the labour market (via job creation and job destruction); income distribution and well-being; skill requirements (and thus formal training via the education system, retraining, life-long learning); and, several fields of regulation (for instance intellectual property rights (IPR), privacy, security and safety investment). Furthermore, digitalisation can be a major enabler of the circular economy (for instance, via mass customisation, smart logistics, smart cities, and smart homes). The policy implications of the next production revolution are so wide-ranging that it would be difficult to mention a major policy domain, which will be untouched by the sorts of sweeping changes noted above.

The need for policy orchestration is, therefore, rather strong. Foresight would assist policy-makers in dealing with these complex changes and challenges in three ways.[3] First, it would facilitate a systemic approach, consider multiple futures and draw on the diverse set of knowledge and experience of participants. Furthermore, a strong sense of ownership among participants could work as an additional factor to keep up the momentum of orchestrated policy design and implementation. Second, the next production revolution is likely to increase uncertainty. Yet, a shared vision, developed – and thus "owned" – by the major stakeholders

3 Foresight can also assist decision-makers in the private sector at firm and sectoral level, for instance in tackling changes induced by the next production revolution in investment opportunities; co-ordinating technological, organisational, business model, financial, managerial and marketing innovations; as well as re-organising and co-ordinating international innovation and production networks.

participating in a foresight process, can reduce uncertainty. Third, the next production revolution is also likely to induce systemic changes, for instance, in the form of emerging innovation ecosystems or radically overhauled national, sectoral or regional innovation systems. A transformative foresight process, aimed at considering and assisting these systemic changes, can contribute to reshaping the prevailing power structures (which might constrain the desired changes) and rejuvenating policy rationales, the overall decision-making culture and methods, and thus the efficacy and efficiency of policies.

Both forecasting exercises and foresight processes rely on a rich arsenal of quantitative and qualitative methods, including simulation, extrapolation, Delphi surveys, horizon scanning, PESTLE (political, economic, social [socio-cultural], technological, legal and environmental) and SWOT (strengths, weaknesses, opportunities and threats) analysis, as well as scenario development (Box 1). Several of these methods are widely used as part of day-to-day decision-preparatory processes, for example, simulation, horizon scanning, SWOT and scenario analysis. A given foresight process relies on a bespoke set of tools and methods to identify and assess in a systematic and transparent way those societal, technological, economic, environmental and policy factors and trends that are likely to affect competitiveness, wealth creation and quality of life.

Box 1: Selected methods for prospective analyses

STEEPV and **PESTLE** analyses provide a simple guiding and structuring framework to identify major driving forces and trends. STEEPV stands for social, technological, economic, environmental, political, and value-driven factors and trends, while PESTLE**,** is a shorthand for political, economic, social [socio-cultural], technological, legal, and environmental ones. **SWOT** analysis is used to identify and categorise significant internal (strengths and weaknesses) and external (opportunities and threats) factors faced by an organisation, a city, a region, a nation or a world region.

Horizon scanning is aimed at detecting early signs of potentially important developments. These can be weak (or early) signals, trends, wild cards or other developments, persistent problems, risks and threats, including matters at the margins of current thinking that challenge past assumptions. It can be completely explorative or a limited search for information in a specific field defined by the objectives of a given task. It seeks to determine what is likely to be constant, what may change and what is constantly changing in the chosen time horizon (short-, medium- or long-term).

Trend extrapolation first identifies a trend that is apparent over time and then projects it forward based on data concerning the rates of change. In shorter-term forecasts a linear or exponential curve (e.g. economic growth, or diffusion of a technology) is extended. To use extrapolation in the longer-term, one should be confident that the underlying driving forces would persist. Using merely quantitative methods, it cannot be assessed if and when ceilings or turning points would be reached.

Simulation creates and experiments with a computerised mathematical model imitating the behaviour of a real-world process or system over time. Simulation is used to describe and analyse the behaviour of a system by asking “what-if” questions about the real system. In this way, it can assist in the design of real systems.

A **Delphi survey** is an expert survey conducted in two or more rounds. In the second and later rounds of the survey, results of the previous round are made available for the respondents to consider. From the second round on, therefore, the respondents are aware of their colleagues' opinions when they give their answers. Giving this type of feedback differentiates Delphi from ordinary opinion surveys. The underlying idea is that the respondents can learn from the views of others, without being unduly influenced by people who talk the loudest at meetings, or who have the highest prestige, etc. Ideally, significant dissenters from an evolving consensus are required to explain the reasons for their views, and this would serve as useful intelligence for others.

A possible set of future situations can be described and discussed at different lengths and for somewhat different purposes in “visions”, “futures” and “fully-fledged scenarios”. These are, therefore, interrelated terms, but not synonyms.
A **vision** is a rather short description (a single paragraph) of a desired future in order to unite and mobilise people to accomplish what is stated in that particular vision statement.

A **future** is a detailed description of a particular situation (outcome of important developments with its major features and interrelationships) in the future. Compared to a vision, it is more detailed, analytical, and neutral. Put succinctly, a vision is normative, while a future is descriptive (a tool for exploration).

A **fully-fledged scenario** (or path scenario) contains a future, as well as the path leading to that future, that is, the major decisions and steps to be taken to reach that particular future.

To be effective, visions, futures and fully-fledged scenarios must be plausible, consistent and offer insights into the future. They should be structurally different, that is, they should not be so close to one another that they become simply variations of a base case. They can draw on many different sources and methods, potentially including all those listed above, as well as brainstorming and specifically designed scenario-building workshops. In contrast to simulation, futures and fully-fledged scenarios can explore relationships and trends for which little or no numerical data are available, including shocks and discontinuities; they can more easily incorporate motivations, values, and behaviour; and they can create images that capture the imagination of those for whom they are intended. They can help decision-makers think about the future in a systematic way by considering a range of plausible futures. These tools also help stimulate creativity and break away from the conventional obsession with present and short-term problems.

A **critical (key) technologies study** aims to identify short-term (three-ten years) research and development policy priorities. Its decisive feature is the set of criteria against which the criticality (the importance) of particular technologies are assessed. It is based on interviews with experts and in some cases on a benchmarking analysis with a selected country or region.

Sources and further readings: Cuhls et al. (2015); the FOREN Guide (Gavigan et al. (eds), 2001); the FOR-LEARN Online Foresight Guide (http://www.foresight-platform.eu/community/forlearn)

Depending on the methodological approach taken, foresight exercises can generate a variety of "products", including thematic reports by panels, lists of priorities, policy recommendations, and roadmaps. These may be generated as intermediary products during the process or as end products. They are often the most visible outputs of a foresight exercise and may be extensively used in policy planning, including by those who may not have been directly involved in the foresight process.

Foresight is practised in many domains and at different levels from sectoral, local, and regional levels, to national levels, and occasionally for world regions, too. Several foresight exercises have focused solely on manufacturing and production, including "Making Value for America: Embracing the Future of Manufacturing, Technology, and Work" (Donofrio and Whitefoot (eds), 2015), "The Future of Manufacturing: A new era of opportunity and challenge for the UK" (Government Office for Science (GOS), 2013), "Industry of the Future: Rallying the New Face of Industry in France" (2013), "The Future of Manufacturing in Europe 2015-2020: The challenge for sustainability (FutMan)" (see Geyer et al., 2003), and "Manufacturing Visions – integrating diverse perspectives into pan-European foresight (ManVis)" (Arilla et al., 2005). Others have covered numerous fields, including manufacturing, and are typically wide-ranging national efforts. They include the various rounds of Chinese, Finnish, German, Japanese, Korean, Russian and UK national foresight programmes, as well as one-off national foresight programmes, for example, in Greece, Hungary, Italy, Poland, Portugal, Slovakia, Slovenia, and South Africa.[4] The large – and increasing – number of foresight programmes suggests that foresight can be a useful policy tool in rather dissimilar innovation systems.

At the same time, continuous horizon scanning activities are tightly embedded in government organisations in several countries. The particularly relevant examples are the UK Horizon

[4] For detailed analyses of these country cases consult e.g. Amanatidou (2013), (2014); Cuhls (2004); (2013); Cuhls and Georghiou (2004); Cuhls et al. (2008); Cuhls et al. (eds) (2009d); Georghiou et al. (2010); Georghiou and Keenan (2006); Havas (2003), Keenan and Miles (2009); Könnölä et al. (2009); Kuwahara (1999); Martin and Johnston (1999); Miles (2005); NISTEP (2005); OECD (1996); Salo et al. (2009); Shin et al. (1999); Stanovnik and Kos (2007); and Yokoo and Okuwada (2012).

Scanning Programme, the Centre for Strategic Futures in Singapore, and Policy Horizons Canada, which has been conducting several metascan projects in recent years.

2.2 Four archetypes of prospective analysis addressing next production revolution issues

Prospective analyses can take many different forms, varying in their specific aims, thematic coverage, geographic scope, focus, methods and time horizons. They also vary in their breadth of thematic coverage (a focus on science and technology (S&T) issues versus a broader focus on innovation and production systems) and their breadth of participation (confined to topic experts versus broader participation). Combining these distinctions, four different archetypes of prospective analysis can be identified (Table 1). These four archetypes[5] are explained in more detail below and illustrated by short descriptions of actual cases.

Table 1: Four archetypes of prospective analyses, with selected examples

		Breadth of thematic coverage →	
		S&T focus	**Focus on innovation and production systems**
Breadth of participation ↓	**Expert-based**	• Productive Nanosystems: A Technology Roadmap, (US, 2007) • Korean Delphi surveys (since 1994, the most recent one conducted in 2015-16) • ManVis (EU, 2003-06)	• Making Value for America: Embracing the Future of Manufacturing, Technology, and Work (US, 2015) • FutMan (EU, 2001-03)
	Participatory	• Exploiting the Electromagnetic Spectrum, (UK Foresight, 2004) • Nanotechnology for Podlaskie 2020 (Poland, 2009-13)	• FinnSight 2015 (Finland, 2006) • BMBF Foresight (Germany, 2007-09, 2012-14) • Advanced Manufacturing Partnership (US, since 2011) • The Future of Manufacturing: A new era of opportunity and challenge for the UK (2013) • The more recent Japanese foresight programmes

Source: authors' compilation

Varying breadth of participation: Expert-based projects versus participatory processes

As highlighted above, foresight is a participatory process, but some types of prospective analysis can be conducted by small(er) expert teams, too. These projects can consider either a single future or multiple futures. In contrast to foresight processes, these are likely to be shorter, and thus cheaper projects, and can have more direct, more visible, and more easily identifiable impacts on certain policy decisions. Critical (or key) technologies exercises fall into this category and have been conducted, for example, in the Czech Republic (Klusacek, 2004), France – where the Technologies Clés exercises are carried out every five years – and the United States. Yet, these types of projects are unlikely to result in a shared vision, reduced uncertainties, and

[5] Archetypes are relevant for analytical purposes to support strategy-setting processes, but real life cases often 'sit' between them. Japan's Robot Strategy (2015), for instance, has a strong S&T focus, but it also explicitly considers several cross-cutting issues, such as human resources, development, regulation, as well as the specific features of several sectors, including manufacturing; services; nursing and medical application fields; infrastructure, disaster response and construction; as well as various branches of agri-food businesses. "Nanotechnology for Podlaskie 2020" also had a strong S&T focus, but regional networking and co-operation were major concerns, too. The US Advance Manufacturing Partnership is another example of combining major features of two archetypes: its reports have been produced by expert groups, but 1 200 participants from industry, academia and government have been involved via regional consultation events, and their views and suggestions are reflected in the final report of the project.

systemic impacts. In particular, it is unlikely that the overall decision-making culture would be altered. Neither would the viewpoints of citizens and non-governmental organisations (NGOs) enrich policy dialogues when this policy preparation tool is used.

Varying breadth of topic coverage: Focus on S&T developments versus focus on innovation and production systems

A given prospective analysis can aim at building strategic visions to guide *technological development* efforts. For example, the UK foresight project on "Exploiting the Electromagnetic Spectrum" (EEMS), completed in 2004, identified four rapidly developing areas in this specific S&T domain, which should represent major areas of economic activity for the coming 10-20 years: all-optical data handling, manufacturing with light, electromagnetics in the near field, and non-intrusive imaging. An action plan was devised for each area by its own group, composed of people from business, academia, user communities, and government and other agencies. A five-year review established that the EEMS project had been largely successful in identifying S&T areas that would be important for businesses and these were still relevant after five years. Many of the actions following the project had encouraged discussion of the importance of the four identified S&T areas, although the review found it difficult to quantify the implications of these activities (DTI, 2004).

Several other projects have also had an S&T focus, including both expert-based exercises, for example, "Productive Nanosystems: A Technology Roadmap" (US, 2007; see UT-Battelle, 2007); the series of Delphi surveys conducted in Korea at five-year intervals since 1994; and more participatory projects, for example, the "National Nanotechnology Foresight Program" (Russia, 2005; see Gaponenko, 2008) and "Nanotechnology for Podlaskie 2020" (Poland, 2009-13; see Kononiuk et al., 2012).[6]

Other foresight projects take a more *systemic view* and aim to build visions for manufacturing, or, more generally, national, regional or sectoral innovation and production systems. For example, "The future of manufacturing: A new era of opportunity and challenge for the UK", a foresight project completed in 2013, considered a wide range of factors shaping the future of manufacturing by looking ahead to 2050 (see Box 2). The two-year project was a major effort: it produced 37 background reports, and besides mobilising the major UK stakeholders, it also involved some 300 industry and academic experts, business leaders and other stakeholders from 25 countries, via workshops organised on three continents (GOS, 2013).

[6] Given the numerous projects on information and communication technology (ICT), industrial biotechnology, chemicals and pharmaceuticals conducted in many different countries, we cannot even aspire to compile a nearly exhaustive list of these prospective analyses.

Box 2: The future of manufacturing: A new era of opportunity and challenge for the UK

Background

"The future of manufacturing: A new era of opportunity and challenge for the UK" project was launched in 2011, as part of the third cycle of UK Foresight,[7] and was sponsored by the Secretary of State for Business, Innovation and Skills.

Process

This two-year project was run by the Foresight Programme of the UK, under the personal direction of the Government Chief Scientific Adviser. The Industry High Level Stakeholder Group, with 34 members from businesses, the government, professional associations, NGOS, and trade unions, chaired by the sponsoring politician, provided strategic advice. The project was overseen by a multi-disciplinary, nine-strong, Lead Expert Group, chaired by a chairman of a major UK company, and consisted mainly of academics. Besides mobilising the major UK stakeholders, the project also involved some 300 industry and academic experts, business leaders and other stakeholders from 25 countries, via workshops held in Asia, Europe and the United States, as well as using other means of consultation.

Outputs

The written outputs include 37 peer-reviewed technical evidence papers, a final report of 250 pages and a summary report of 54 pages, all made available online. The project considered several factors shaping the key future characteristics of manufacturing by looking ahead to 2050. These include *new business models*, e.g. the "servitisation" of manufacturing; the *extension of value chains*; major *market trends and opportunities*; "*onshoring*" *of production* back to the UK; and the increasing share of *foreign ownership*. The likely impacts of five pervasive and six secondary *technologies* are also spelt out, as well as the features of *future factories*, *environmental trends* and *skills* requirements. Several types of *financial* gaps are also identified. Based on this systemic view of the future of manufacturing, the final report thoroughly explores the policy implications of all these factors and trends. Rather than coming up with naïve suggestions based on simple trend extrapolation, it stresses the need to take an integrated view of value creation in manufacturing; follow a more targeted approach to supporting specific stages of manufacturing based on the value-chain approach, and a systemic understanding of STI (science, technology, and innovation) and industrial policies; and enhance government capability in evaluating and co-ordinating policy over the long term.

Impact

This project has not been evaluated yet.

The most recent rounds of the Japanese national foresight programme have shifted from an exclusive technological focus to a broader approach, considering, for example, market, health, environmental, skills and ownership issues, too, when presenting a plan for the "Revitalization of Japanese Industry" (Prime Minister's Office, 2013, 2014).

The US National Academy of Engineering (NAE) published a major report in 2015 taking a broad view of manufacturing: "Making Value for America: Embracing the Future of Manufacturing,

[7] The UK was among the frontrunners in Europe to use foresight, starting in the early 1990s. Given the lessons learnt, the aims, methods, and organisation of these activities changed whenever a new cycle was launched. The first cycle (1993-98) aimed at identifying S&T priorities for the entire UK research system. The second cycle (1999-2001) was concerned with promoting broader participation in dialogues on business-related issues, mobilising a wider variety of participants, and also broadening the issues considered, especially by putting more emphasis on quality of life. The third cycle (2002-present) significantly changed the scope of analysis to anticipate policy-relevant changes and identify how S&T can serve these direct, sharply-focused policy needs (e.g. to tackle flooding, cyber crime and obesity). It restricted the number of projects running at any one time to three to four, as well as the time available to complete a given project (12-18 months). It also became a precondition to have a committed sponsor, i.e. a high-ranking politician or policy-maker who is committed to take up the recommendations stemming from a given project. See Georghiou et al. (2010), Keenan and Miles (2008), and Miles (2005) for a thorough analysis of the UK foresight cycles.

Technology, and Work" (Donofrio and Whitefoot (eds), 2015). Unlike the UK foresight process on the future of manufacturing, it is based on the work of a smaller group of experts: a committee established by the NAE, staff members and contributions by fellow S&T experts.

The Advanced Manufacturing Partnership (AMP) has been another important US initiative, launched by the president in 2011. Following a successful first stage, leading to several policy recommendations (PACST, 2012), its second stage (AMP2.0) was convened in September 2013, yielding further recommendations, published in a 2014 report (PACST, 2014). It has been followed up by a US government-funded initiative called "MForesight: Alliance for Manufacturing Foresight" (see Box 3).

Box 3: US initiatives: The Advanced Manufacturing Partnership (AMP) and MForesight: Alliance for Manufacturing Foresight

Background

Acting upon the recommendation of his S&T advisers, the US president launched the Advanced Manufacturing Partnership (AMP) in 2011, a national effort bringing together businesses, universities, the federal government, and other stakeholders to identify emerging technologies with the potential to create high-quality domestic manufacturing jobs and enhance US global competitiveness.

Process

The AMP Steering Committee initiated five workstreams on technology development; shared infrastructure and facilities; education and workforce development; policy; and outreach, each with their own specific objectives. Background reports were produced on these themes. Extensive consultations with stakeholders were organised to identify opportunities for investments in advanced manufacturing that have the potential to transform US industry. Four regional meetings were conducted in different states, attended by 1 200 participants from industry and academia. The sixth background report summarised the main insights from these meetings. The second phase of AMP was convened in September 2013.

Outputs

Two major reports were published by the AMP Steering Committee. The first, entitled "Capturing Domestic Competitive Advantage in Advanced Manufacturing" (PACST, 2012), focused on three pillars to create the necessary conditions for maintaining US leadership in advanced manufacturing: enabling innovation (six recommendations); securing the talent pipeline (six recommendations), and improving the business climate (four recommendations). The report's recommendations included: developing a model for evaluating, prioritising, and recommending federal investments in advanced manufacturing technologies; public-private partnerships, including the National Network for Manufacturing Innovation, to focus on advancing high-impact technologies and models for collaboration that encompass technology development, innovation infrastructure, and workforce development; and public intervention to increase private investment in advancing manufacturing in the United States.

The second report, entitled "Accelerating US Advanced Manufacturing" (PACST, 2014), also used the three pillars identified in phase 1 to organise its 11 recommendations. These were concerned with policy governance (devising a national plan on emerging manufacturing strategy and creating an advisory consortium, as well as a shared National Network for Manufacturing Innovation (NNMI) governance structure); new public-private manufacturing research and development (R&D) infrastructure; processes and standards (e.g. on interoperability of technologies and cyber security); changing the image of manufacturing to attract talents; education and skill development, as well as a system of nationally recognised, portable, and stackable skill certifications; improving the flow of information on technologies, markets and supply chains to small and medium-sized enterprises (SMEs); and reducing the risk associated with scaling up advance manufacturing technologies via the creation of a public-private scale-up investment fund, improved information flow between strategic partners, government and manufacturers, and tax incentives to foster manufacturing investments. A specific recommendation on implementation was also added, urging the National Economic Council and the Office of the S&T Policy to submit a set of recommendations to the president within 60 days.

Impact

Following the recommendations of the first AMP report, "A National Strategic Plan for Advanced Manufacturing" was published in February 2012; the Advanced Manufacturing National Program Office (AMNPO) was formed as an inter-agency team to co-ordinate and collaborate on cross-cutting initiatives; federal funding for advanced manufacturing R&D was increased by nearly 20% in the 2013 fiscal year; pilot institutes were opened on advanced manufacturing; and the patent system was reformed. (Further impacts are reported in PACST, 2014.)

As a specific impact, AMP has been followed up by a US government-funded initiative called "MForesight: Alliance for Manufacturing Foresight". MForesight was established in 2015 and aims to "serve as the voice of the national advanced manufacturing community, providing government and industry with information and analyses about emerging technologies, workforce training, and opportunities for public-private partnerships that strengthen US competitiveness." It has six main objectives: 1) identify and prioritise technologies worth developing and expanding; 2) prepare reports on emerging technologies for future investment; 3) identify and share success cases in technology commercialisation and workforce development; 4) communicate opportunities and challenges to business, government, and academic players in advanced manufacturing; 5) promote career opportunities in engineering and advanced manufacturing; and 6) share technology forecasting results to help the US manufacturing community stay ahead of the curve. These objectives are to be achieved by organising interactive public workshops, small expert gatherings, and virtual roundtables, publishing reports, articles, and conference presentations, as well as using social media. (For further details, see http://mforesight.org/about-us/)

In summary, countries have applied a multitude of approaches and methods to identify and prepare for the opportunities and challenges that are likely to be raised by the next production revolution. Given the interrelatedness of technologies, new materials and processes, and new business models relevant to the next production revolution, a systemic approach to foresight seems more appropriate to inform next production revolution policies than a narrower S&T focus. Furthermore, participatory approaches enable various innovation and societal actors to bring together a much richer set of knowledge, experience, values, aspirations, perspectives and strategies to analyse the complex technological, economic, social, and potentially environmental changes that are expected. Yet, in certain cases, narrower expert-based projects have an important advantage: their results are normally produced more quickly and at a lower cost.

3 Potential benefits of foresight and its roles in devising policies

This section provides an overview of the potential benefits of foresight by considering its intended and unintended impacts and analyses six major possible roles for foresight in shaping and implementing policies.

3.1 Potential benefits of foresight

As shown by a range of studies (e.g. Havas et al., 2010; Cassingena Harper, 2016), foresight can help decision-makers cope with an uncertain future. Foresight can aid *policy formation* by generating reports that analyse the dynamics of change, future challenges and related options for action. Such analysis is used by policy-makers as input for issue definition, as well as for designing policies. This can provide the foundations for more robust policies, foster systems thinking, offer a new framing of policy issues, and turn long-term concerns into urgent policy priorities. Foresight can also play a role in making *policy implementation* more effective by facilitating the mobilisation and alignment of key stakeholders, and supporting policy co-ordination. In this way, foresight can supplement traditional top-down policy instruments, by shaping the mindsets of those participating in the process, and thus preparing the ground for complementary actions and strategies.

For these benefits to materialise, foresight needs to achieve impacts in different terms:

- in cognitive terms, to help prepare the mindsets of people for possible changes (new contexts, new socio-economic processes), which would require new ways of thinking;
- in procedural terms, by contributing to a change in decision-preparation processes, for instance, by including more, and a wider set of, stakeholders;
- in substantive terms, to actually change the content of policies;
- in terms of structural and/or organisational changes.

The benefits mentioned above correspond to the intended impacts of foresight, but it is far from certain that such intended impacts will actually be achieved. Some of the critical factors and conditions necessary to reap the benefits of foresight are discussed in the next section.

Intended impacts also need to be seen against the backdrop of the policy governance system in which the foresight process is embedded. In essence, a foresight process can either reinforce the existing system of policy governance or contribute to transforming it. In this way, the appropriate design of a foresight process is dependent on prior problem perception. In particular, the frame of reference is key, that is, how the problem area is delineated and whether the existing policy governance sub-system, or other parts of the innovation system, are to be reinforced or transformed.

In addition to the intended impacts, there can also be unintended impacts, which can be either positive or negative. Unintended impacts, by their very nature, can rarely be anticipated: they often arise from indirect and unknown pathways of influence. For instance, the changes in the mindset of policy-makers and other stakeholders, which a foresight activity have triggered, may help strengthening or building capabilities of strategic thinking that may be equally useful in other policy domains. The same can be said about new networks built and knowledge created.

The widely known problem of attribution arises when identifying and interpreting the impacts of foresight. Other factors than a given foresight process also affect policies, and foresight may well just reinforce and integrate isolated initiatives that have been around for a while. As a consequence, it is often difficult to observe and measure foresight impacts in a precise way. The problem of attribution is particularly pertinent in relation to far-reaching impacts, such as, for instance, on economic performance. The pathways of influence are multifaceted and indirect, with many other factors coming into play. The timing of expected impacts is also an important consideration, since while some effects may be almost immediate, others may take a long time to arise.[8]

Disentangling how impacts unfold is a challenging task (Georghiou and Keenan, 2006). In the foresight literature, it is often argued that the "process" benefits are (at least) as important as the "products", that is, reports, lists of priorities, policy recommendations, roadmaps, etc. for achieving impacts (Amanatidou and Guy, 2008). This is because the process is more likely than any report to change the mindsets of decision-makers and help structure new networks (without denying the influence of well-written reports and policy recommendations).[9]

3.2 Possible roles of foresight in shaping and implementing policies

Providing the foundations for more robust policies

Foresight explores different possible futures. In uncertain times, thinking in terms of multiple future states is a necessary precondition for devising policies to cope with unexpected developments. The Shell experience of the early 1970s is a well-known example: having considered an oil crisis as one of its possible futures, the company was better prepared than its

8 For a more detailed account on possible intermediate and ultimate impacts, see, e.g. Havas et al. (2010).
9 Process benefits can also occur in terms of improved decision-preparation processes, as well as more efficient structural and/or organisational set ups.

competitors to tackle this – until then an unthought-of – situation once it occurred (Jefferson, 2012; Shell, 2013). Foresight can also make policies more robust by bringing together into policy dialogues participants with diverse backgrounds, in order to tap into their wide-ranging accumulated knowledge, complementary experiences, aspirations and ideas. For example, the Finnish governmental foresight report on "Long-term Climate and Energy Policy: Towards a Low-carbon Finland" (2009) used a participatory process involving stakeholders with diverse backgrounds and interests to explore four different scenarios that showed various pathways towards a low-carbon Finland, with each pointing to different implications for industry, consumers and government. Ultimately, the project triggered a dialogue between the government and the parliament on the future of the country and provided a foundation for policy strategies stretching beyond parliamentary cycles.

Fostering systems thinking

In a complex world, phenomena cannot be understood in an isolated manner, but must be seen in context, taking into account a range of different viewpoints. Foresight, on account of its participatory nature, and drawing on relevant methods, is a means to incorporate different perspectives when exploring possible futures and to bring to the fore a range of relevant influences on, and impacts of, the issue in question. The recent British foresight project on "The Future of Manufacturing: A new era of opportunity and challenge for the UK" provides a good example of this. It considers several factors shaping the key future characteristics of manufacturing by looking ahead to 2050 (see Box 2). Based on this systemic view of the future of manufacturing, the report thoroughly explores the policy implications of all these factors and trends. It stresses the need to take an integrated view of value creation in manufacturing; follow a more targeted approach to supporting specific stages of manufacturing based on the value-chain approach and a systemic understanding of STI (science, technology and innovation) policies, as well as industrial policies; and enhance government capabilities in evaluating and co-ordinating policy over the long term. The process itself can also have systemic impacts, with intense dialogues strengthening existing, or creating new, networks of major actors, and reinforcing a future-oriented way of thinking. The novel, participatory methods used in foresight can also reshape the overall culture of policy-making, especially in the domains of education, industrial, and innovation policies.

The US AMP project has also taken a systemic view, stressing the importance of governance structures, processes and standards, skill formation and recognition, financial and other factors constraining investments in advanced technologies, strategy-making capabilities of SMEs, and networking among strategic partners (see Box 3). Similarly, "Making Value for America: Embracing the Future of Manufacturing, Technology, and Work" (Donofrio and Whitefoot (eds), 2015) has also considered manufacturing in its broader context, as has the study "Revitalization of Japanese Industry" (prime minister's office, 2013, 2014).

New framing of policy issues

Government bodies tend to be organised along the lines of well-established, and rigidly demarcated, policy domains. In such an environment it is often difficult to find an appropriate place for cross-cutting research domains or new modes of delimiting them (e.g. shifting from S&T-led to societal challenge-driven research and innovation projects). Foresight processes have the potential to change not only the framing of policy issues, but also to induce organisational innovations.

The German Federal Ministry of Education and Research (BMBF) Foresight is a case in point (see Box 4): it aimed to identify new focal areas in research, defining cross-cutting issues and interdisciplinary topics that require attention. Two of these novel future fields were called „Human-Technology Co-operation" and "ProductionConsumption 2.0". Both fields obtained high visibility in policy debates and triggered an intense discussion about the future of manufacturing in Germany, eventually contributing to and shaping the concept of what is nowadays called

"Industrie 4.0". One of the fields was subsequently also mirrored in the creation of a new division in BMBF in 2010, called "Demographic Change and Human-Technology Co-operation".

Box 4: BMBF Foresight, Germany

Background

The German BMBF Foresight was launched in 2007, with a follow-up in 2012. It builds on earlier foresight activities of BMBF using different methods (Key Technologies, Delphi, FUTUR Process). The BMBF Foresight needs to be viewed in the context of the German High-tech Strategy (aiming to concentrate research efforts on areas of future promise) and the Excellence Initiative (providing top-up funding to leading universities and research centres). The main objectives of the 2007 round were as follows:

- identify new focal areas in research and technology that the BMBF should address;
- define cross-cutting issues and interdisciplinary topics that require broader attention;
- help forge strategic partnerships of various departments within the ministry and different groups of actors in the innovation system, who are able to jointly address the areas and topics identified in a strategic manner; and
- propose priorities for concrete measures to be adopted to promote the fields in question.

Process

The BMBF Foresight, co-ordinated by a team of external experts, employed a combination of analytical and exploratory methods, ranging from expert surveys and participation in critical reflection rounds, to the co-shaping of policy advice. In a first, largely analytical phase, an overview of emerging future topics was produced. It was subsequently consolidated by an on-line Delphi survey and followed by a series of workshops, designed to deliver the necessary "sense-making". The process delivered 14 future research and innovation topics and 7 cross-cutting future fields. Suggestions were also made regarding actors to be involved, partnerships to be formed, and actions to be taken.

Outputs

The outputs of the BMBF Foresight were compiled in a set of main reports: Cuhls et al. (eds) (2009a), (2009b).

Impact

One of the most visible cross-cutting fields was ProductionConsumption 2.0, which integrates future technological and social changes along the entire production-consumption chain. While the future topics could be integrated rather easily in the ministry's strategy and policies, in particular the High-tech Strategy, it was much more difficult to integrate the cross-cutting fields. Addressing cross-cutting issues is difficult in an environment of demarcated terrains of S&T fields and a rather monolithic culture with limited openness to interdisciplinary approaches.

However, the embedding of highly innovative cross-cutting future fields in a process that offers also a number of "quick wins" in terms of more traditional research and innovation topics may have been a wise approach. It allowed infusing some non-conventional insights into a context that was otherwise mainly receptive to conventional research and innovation topics.

Critical factors

The BMBF Foresight was successful in avoiding the fate of several foresight projects in other countries where changes in government significantly reduced the chances of foresight results being taken up by the incoming government. By preparing emerging topics with a significant potential for exploitation, sufficient room was left for political choices in different kinds of strategy formation processes.

Moreover, dedicated efforts to interact closely with the sponsors of the BMBF Foresight were an integral part of project design. The foresight team was expected to engage intensely with different interested departments in the BMBF. This interaction may have been a meandering in search for and discovery of new topics, but it strengthened the interactions and debates within and across government departments.

Finally, even the less exploited results of BMBF Foresight turned out to be a valuable resource for subsequent policy-making, because they served as an "information reservoir" for further systemic change. In the meantime, experiences have been accumulated in public administration on how to make effective use of foresight, and if the process is continued on a regular basis, as is planned, then the reservoir fields identified in the different rounds may get reinforced during the next cycle(s).

Turning long-term concerns into urgent policy priorities

Agenda setting is about deciding which policy issues deserve most attention. Priority issues need to be identified, selected in a justified manner, and specified. Whether or not a problem is moved onto the policy agenda is a matter of the perceived urgency of the issue, and of the perception that government action may be necessary to tackle it.

Foresight can play a beneficial role for agenda setting in several regards, by making transparent why a seemingly long-term issue may require immediate policy attention. First of all, by focusing debates on the long-term, it contributes to changing the perception of longer-term issues and allows turning them into urgent ones. In this way, foresight can be a means to make explicit why long-term issues need to be treated with urgency on today's policy agendas.

Second, and related to the long-term perspective inherent to foresight, novel future-oriented rationales to underpin and justify policy interventions can be developed in the context of foresight, providing arguments justifying government intervention. In the case of the Finnish governmental foresight reports, this effect is enabled and reinforced by the dialogue between the parliament and government in developing the reports. Issues of a longer-term nature (e.g. climate change, competitiveness and well-being in society) were positioned high on the policy agenda due to the prominence of the corresponding government foresight reports, together with the underlying rationales to justify that positioning.

Finally, visions often play an important supporting role in making long-term issues more palpable, because they serve as sources of inspiration and orientation for prioritisation and underlying rationales (see Box 5 for examples). While they may have, in the first instance, an influence on the mindsets of individual policy-makers and stakeholders, they also provide novel and powerful ideas for the formulation of rationales to legitimise and justify priorities and scope for government intervention, and can thus strengthen the credibility of policy agendas.

Box 5: Manufacturing visions

United Kingdom

"Constant adaptability will pervade all aspects of manufacturing, from research and development to innovation, production processes, supplier and customer interdependencies, and lifetime product maintenance and repair. Products and processes will be sustainable, with built-in reuse, remanufacturing and recycling for products reaching the end of their useful lives. Closed loop systems will be used to eliminate energy and water waste and to recycle physical waste." (excerpt from "A new vision for UK manufacturing" presented in GOS 2013, p. 6)

United States

"A new generation of networked-based information technologies, data analytics and predictive modeling is providing unprecedented capabilities as well as access to previously unimagined potential uses of data and information not only in the advancement of new physical technologies, materials and products but also the advancement of new, radically better ways of doing manufacturing. (…) Our vision is that such integration via ASCPM will increase productivity, product and process agility, environmental sustainability, energy and raw material usage, and safety performance as well as economic performance – and thereby comprehensively improve the competitiveness of U.S. factories of varied sizes and complexity. In particular, broader application of ASCPM technologies has great potential in energy-intensive manufacturing, and integral to use of big data analytics to drive manufacturing decisions. (…)

Visualization, Informatics, & Digital Manufacturing (VIDM) is a set of integrated, crosscutting enterprise-level smart-manufacturing approaches, leveraging the current advances in information technology systems and tools that will improve U.S. manufacturing competitiveness through end-to-end supply-chain efficiency, unprecedented flexibility, and optimized energy management to achieve error-free manufacturing of customized products and components from digital designs, when needed and where needed. (…) Our vision is that VIDM (…) will rapidly change the way manufacturers use and exchange information to plan, support, source, deliver, and make commercial products in the U.S. (…)

Our vision is that the U.S. will train a workforce that can invent, adapt, maintain, and recycle materials critical to U.S. infrastructure, defense, medical care, and quality-of-life. This vision will also accelerate the transition from lower to higher TRL/MRL maturity, to enable faster and broader industry adoption."
(excerpts from "Accelerating U.S. Advanced Manufacturing", PCAST, 2014, pp. 67-70)

Facilitating the mobilisation and alignment of key stakeholders

Besides exploring possible futures, most foresight activities also aim to achieve a common understanding of what a desirable future might be. Such *visions* and, associated to them, more operational *roadmaps*, can be powerful instruments to assemble different key players in a domain around a *shared agenda*. The main benefit of such visions, roadmaps and strategic agendas is that they help reduce uncertainty about the ambitions of partners and competitors, and thus assist making long-term investment decisions. Moreover, once participants arrive at a shared vision, they can expect that most of their fellow participants would take steps to achieve that chosen future state, and thus align their future actions to the jointly identified favourable future. The first attempt to develop such shared visions for manufacturing at an EU level was the FutMan project ("Future of manufacturing in Europe 2015-20 – the challenge for sustainable development"), carried out in 2001-03 (Geyer et al., 2003). By way of scenario development, it explored different images and pathways of the future of manufacturing, as well as building blocks of a joint EU vision. Interestingly, it rightly anticipated new technological developments, such as additive manufacturing (3D printing). Results from FutMan nurtured the formation of the MANUFUTURE European technology platform, which brought together the main stakeholders from academia and industry. The MANUFUTURE vision and strategic research agenda was further underpinned by the follow-up project to FutMan, called ManVis.

Supporting policy co-ordination

Foresight usually aims to identify future issues that often cut across established areas of policy interest. By way of involving participants from different policy domains that are likely to be affected by these novel developments, a futures dialogue can be initiated across the boundaries of these fields. This can be a dialogue that contributes to creating a shared perception of emerging challenges, and complementary, if not joint, strategies to address them. Policy co-ordination can be fostered both horizontally (i.e. across policy domains, or between the parliament and government) and vertically (i.e. between ministries and executive agencies). The FinnSight 2015 project, conducted in 2006, illustrates both effects (see Box 6). Its focus was on the change factors that had significant impacts on Finnish business and society, and on the identification of areas of expertise that would foster well-being and competitiveness. FinnSight 2015 informed the dialogue between the government and parliament on these issues. Moreover, its results were not only taken up by the two implementing organisations, that is, the Academy of Finland and Tekes, the National Technology Agency of Finland, in their respective strategy development, but were also important for the subsequent establishment of Strategic Centres for Science, Technology and Innovation (e.g. CLEEN Oy, the energy and environment cluster).

Box 6: Governmental Foresight Reports Finland – Finnsight 2015

Background

The Finnish Governmental Foresight Reports have been prepared by the Prime Minister's Office and a dedicated task force since 1992. These reports are debated in government, then presented and discussed in the Finnish Parliament in the second year of each parliamentary term. The 2006 edition of the governmental foresight Report – FinnSight 2015 – was dedicated to industrial futures. FinnSight 2015 aimed at identifying future change factors and challenges of research and innovation activities, and analysed the areas of expertise that would foster well-being in society and the competitiveness of businesses by means of scientific research and innovation activities (Academy of Finland and Tekes, 2006).

Process

FinnSight 2015 was jointly implemented by the Academy of Finland and Tekes. It focused on the change factors that may impact on Finnish business and industry as well as Finnish society on a time horizon of 2015, mapped them with current areas of competence in Finland, and suggested areas for future building of focal competence areas. It drew mainly on the work of ten sectoral expert panels, with representatives from business and civic organisations. The panels engaged in qualitative exploration of change factors, as well as in semi-quantitative online assessments. Cross-panel interactions enabled the identification of cross-cutting areas.

Outputs

The main output of the project was a major report to the Parliament (Academy of Finland and Tekes, 2006), which served as a basis for parliamentary debates, but also fuelled public debates and strategic thinking in Finnish companies and clusters.

Impact

These governmental foresight reports provide an opportunity to move future issues onto the policy agenda. This happens directly when the reports are taken up in parliamentary and/or public policy debates (and indirectly, when foresight experts contribute to the preparation of the reports). Although it is hard to confirm a direct influence on policy-making, there are indications that recent Governmental Foresight Reports have enhanced the awareness and importance of futures thinking in Finland. The institutionalised nature of the reports, the backing from the highest level of the government and the Parliament, the methodological soundness, as well as the wide outreach to the best knowledge available in the country all contribute to enhancing their influence on agenda setting. Given the high-level status of the reports, they also help ensure the continuity of agendas in the course of the shift from one government to the next.

These reports also exert an influence outside of government. FinnSight 2015, for instance, has been important for the establishment of Strategic Centrers for Science, Technology and Innovation. Results have also been used to reinforce strategy work at the Academy of Finland and Tekes.

Critical factors

Finland is a country with a well-developed foresight culture, including a high absorptive capacity for foresight. A governmental foresight network connects the many government departments and public agencies with dedicated foresight units, which conduct foresight on a regular basis. There is also a sound awareness of the main barriers and pitfalls associated with government-led foresight processes, and great care is taken to address them, including:

- information overload due to open and shared information;
- resistance to making foresight material publicly available;
- excessive bureaucratic effort leading to unwillingness to engage;
- failure to identify suitable experts and engage with them;
- poor quality of source material and analyses;
- inconsistent process design;
- insufficient continuity of interactions with users of foresight results;
- lack of need for foresight perceived by society.

3.3 Transforming the policy governance and other sub-systems

Besides shaping policies, informing, advising and implementing policies as discussed above, foresight can also play a role at a systemic level. Thus, it is worth digging one layer deeper by considering if a foresight process is aimed at strengthening an existing innovation system (or any of its major sub-system, including the policy governance sub-system) or on the contrary, at reconfiguring it. In other words, another major potential role of foresight in shaping the new production revolution is transforming the industrial and innovation policy governance sub-systems and other parts of an innovation system.

Foresight offers opportunities for reflexive learning in a given policy domain. As a result, participants might conclude that the prevailing perspectives on policy issues and/or the configuration of the policy governance sub-system may be inadequate to address the economic, societal or environmental challenges they are facing. They can also recognise that the predominant "silo-thinking" in government circles hinders the orchestration of various policy actions that need to be aligned to be capable of effectively tackling major issues.

These insights can lead to the reconfiguration of the policy governance sub-system, or to be more modest, initiate further reflections concerning the adequacy of the configuration of a current policy governance sub-system to address systemic issues (e.g. the emergence of new RTDI practices and the evolution of new innovation ecosystems, also characterised by new business models.[10]

3.4 Summary of benefits and impacts

In summary, foresight can influence innovation activities and hence economic performance through a web of direct and indirect impacts. Through its process benefits and products (e.g. reports, visions, recommendations, roadmaps) it is likely to shape policy-making. However, given the complexity of the pathways of influence – indicated by the sheer number and diversity of actors involved in a foresight process and subsequent policy formation – it would be a rather demanding task to establish a clear and direct link between an actual foresight process and its impacts on policies. It is further complicated by indirect impacts on innovation and economic activities and performance, structural changes, and ways of thinking and behaviour of the major actors of an innovation system.

Furthermore, the potential roles and expected impacts will vary by type of prospective analyses. Participatory processes mobilise a wider set of knowledge, experience, aspirations and world views compared to an expert-based project. Hence, more novel and unconventional ideas can be expected, which can be better substantiated given the diversity of viewpoints, since ideas would be more thoroughly tested and contested from various angles. Furthermore, a deeper, more thorough understanding of major long-term challenges and their social, environmental and economic repercussions is more likely to stem from participatory processes. Policies, therefore, would be better substantiated and their credibility and legitimation strengthened. A wider set of policies could be more consciously orchestrated, increasing the effectiveness of their implementation.

Clearly, prospective analysis focusing on innovation and manufacturing systems would consider a broader set of issues than S&T centred projects, with benefits for both policy preparation and implementation. Given the complex issues – interrelated technological, economic, societal and environmental opportunities and challenges – brought about by the next production revolution, a systemic approach seems to be more appropriate as a foundation for devising policies aimed at tackling these far-reaching and profound changes. The country case boxes featured in this

[10] Main features of various types of STI policy governance sub-systems and the conditions for a successful transformative foresight process are analysed in detail in Havas and Weber (2017), illustrated by actual cases.

chapter bear this out. Yet, in certain contexts, an S&T centred prospective analysis can also be useful, but it should be clear from the outset that different and only more limited benefits and impacts can arise from this approach.

4 Factors and conditions critical to reaping the benefits of foresight

This section considers the most important factors to keep in mind to reap the benefits of foresight. These include chiefly political and policy factors (4.1–4.5), as well as various methodological considerations (4.6–4.8).

4.1 A committed client and clear objectives

Both successful and less successful foresight projects point to the same major conclusion: a fundamental condition for achieving impact is to have *a committed client*, that is, an organisation or a set of organisations with decision-making competences, that would be open to the recommendations stemming from the foresight process and willing to act upon these proposals (including acting as a "foresight champion" in case other bodies need to be involved in making decisions). Without this sort of commitment, much of the time and effort participants put into a foresight process would be wasted, together with the public money spent to cover organisational and other costs. By way of example, the second cycle of the UK foresight programme (1999-2001) had weak impacts for two main reasons: it had too many projects running without a clear focus; and it lacked clients – or project "owners" – who felt a strong need to tackle a perceived policy problem through a foresight process. Learning from this experience, the third cycle, launched in 2002 and still on-going, has only three to four parallel projects running at any one time, and all these have a "sponsoring" minister, who usually chairs the stakeholder group overseeing the project. The sponsoring minister, therefore, feels ownership and is willing to take up the proposals stemming from the project. Equally good ideas, developed without his or her active involvement, might well be perceived as recommendations by "aliens", and would probably have a lower chance of implementation (see Box 2).

A coherent project plan should also be devised in close co-operation with the client(s) to determine foresight's focus, main objectives, time horizon, geographic scope, and the choice of appropriate participants and methods.

4.2 Continued support and sustained efforts over time

Continued support is needed to reap the benefits of foresight activities: it takes quite some time – often several rounds of activities – to affect policies, ways of thinking, policy-making cultures and governance systems. For instance, the project on "The Future of Manufacturing: A new era of opportunity and challenge for the UK" lasted for two years and required significant resources (see Box 2). In other cases, a succession of projects was needed: the European MANUFUTURE technology platform has capitalised on the results of FutMan and ManVis (both mentioned above) when defining its vision and strategic research agenda. The MANUFUTURE technology platform has played a role in "moulding" the manufacturing elements of the European Union's Research and Technological Development (EU RTD) Framework Programmes towards a new manufacturing paradigm. The Seventh Framework Programme and Horizon 2020 would have evolved differently in the absence of the ManVis and FutMan projects. These strategic dialogues are facilitated now by the Intelligent Manufacturing Systems project, spanning three continents (http://www.ims.org; see also Cagnin and Konnola [2014]).

In those countries where national foresight programmes were one-off initiatives (e.g. Greece and Hungary), the opportunities to reap the benefits – as well as for "learning by doing" – have been severely constrained. This contrasts with the situation in those countries that have conducted several foresight cycles over many years (e.g. Germany, Japan, the UK; see Boxes 2 and 4).[11]

4.3 Learning by doing to absorb insights

Foresight is still a new, unconventional way of thinking, communicating and preparing strategic actions in many countries, and thus learning about foresight is crucial. Readily available reports on actual cases, together with methodological guidelines, would certainly help policy-makers, foresight practitioners, stakeholders (as potential participants) and opinion-leaders better understand and assess the relevance of foresight, but deep learning can only occur through practice. As there is no single blueprint for a "perfect" foresight process, on the one hand, and the challenges to be tackled and the opportunities to be exploited constantly evolve, on the other, this *learning process* is particularly important. It is forcefully illustrated by the major changes introduced in the third cycle of UK foresight (see Box 2). Another telling example is the Japanese national foresight programme, whose most recent rounds have shifted from an exclusive technological focus in the 1970s and 1980s to a broader socio-technical approach. This shift reflects changing perceptions in Japan of the relationship between technology and society.

4.4 Supportive organisational and political cultures

The ultimate condition for high-quality and useful foresight is having a deeply rooted *foresight culture* in place. Nurturing foresight culture is a lengthy and demanding process, which cannot be planned in advance by setting deadlines and milestones. Continued support to foresight, together with the ensuing learning process, is necessary to this end. For example, since 1992, the Finnish government, under the responsibility of the Prime Minister's Office and supported by external partners, has prepared a foresight report to the Finnish Parliament once per parliamentary term. These reports have strengthened long-term thinking in Finland, created a dialogue between government and parliament on future issues of national relevance, and provided a stable strategic framework for policy that goes way beyond election cycles (see Box 6). In contrast, changes in government have prevented the continuation of national foresight programmes, and thus the creation of a foresight culture, in countries like Greece, Hungary, and Turkey.

4.5 Close links to decision-making – but with intellectual autonomy

In some cases, countries have conducted foresight for its own sake – because "we are at least as smart as our neighbours", or it has been promoted by international organisations. To make foresight useful, it should be *embedded in the decision-making system* (see Boxes 2 and 6). Its timing, relevance to major issues faced by a given society, and co-ordination with other significant policy initiatives are critical. The German BMBF Foresight (2007-09) explored future issues and challenges to underpin German STI policy, and was closely connected to the German High-tech Strategy. In this way, new focal areas in research and technology were identified, defining cross-cutting issues and interdisciplinary topics that require attention. This co-ordination also helped forging strategic partnerships within BMBF and with actors of the German innovation system (see Box 4).

It is also important to find an organisational set-up that can ease *the inherent contradiction* between the need for foresight to be *embedded* in the decision-making system (to gain political

[11] For a concise overview of some of these country cases see e.g. Havas and Weber (2017), for more detailed analyses consult e.g. Amanatidou (2013), (2014); Cuhls (2013); Cuhls and Georghiou (2004); Cuhls et al. (2009); Georghiou et al. (2010), Georghiou and Keenan (2006); Havas (2003), Keenan and Miles (2009); Kuwahara (1999); Martin and Johnston (1999); Miles (2005); NISTEP (2005); OECD (1996); and Yokoo and Okuwada (2012).

support), and the need to *maintain intellectual autonomy* (to facilitate original thinking). It is not a trivial task to strike a balance between these requirements, and any solution can only be context-specific. For example, given the legacy of central planning, especially its all-pervasive hierarchical features, it was decided that TEP, the Hungarian Technology Foresight Programme (1998-2000), should be driven by its participants rather than by the government agency that initiated and financed it, and that the programme should enjoy a high level of autonomy. Even with these features, some of the participants perceived foresight at the beginning of the process as central planning in disguise. TEP, therefore, was not embedded in decision-making structures. Moreover, the government agency that launched TEP did not have the necessary political clout to convince the major ministries to act upon the policy proposals produced by TEP. The change in government during the lifetime of TEP was also unfavourable (Havas, 2003). Thus, only a few recommendations have been implemented in a slow and non-linear process (Georghiou et al., 2004).

4.6 The chosen type of foresight and its main objectives need to "fit" the purpose

For foresight to be effective, it is important to consider the relationship between its design (in terms of focus, methods and level of participation), on the one hand, and characteristics of the policy governance sub- system (especially the existing decision-making culture and methods; the commitment of decision-makers to rely on the results; the availability of methodological skills and experience; the level of capabilities for strategic thinking) in which it is supposed to be embedded, on the other. In many cases, a foresight process needs to resonate with the prevailing policy governance sub-system to be effective, that is, it needs to be compatible with the culture of participation and respect fundamental institutional and organisational boundaries (e.g. in terms of being restricted to a single policy area rather than being cross-cutting in nature). This is usually the case in foresight activities that aim to set thematic priorities, but without questioning the structural and institutional conditions in a given area.

However, foresight processes that aim to set thematic priorities need to be clearly distinguished from those that aim to induce systemic change (Havas and Weber, 2017). This is a crucial distinction in the context of the next production revolution, given the necessity for fundamental changes in organisational structures, institutions and relations, thus pointing to a need to also question major elements of the system of policy governance. In such cases, it is more suitable to design a transformative foresight that contribute to changing the policy governance sub-system.

This argument also shows that prior to the design of a foresight process, one needs to have a reasonably good preconception of the magnitude of the challenges ahead, that is, when defining the scope and purpose of the foresight.

4.7 Facilitate the use of foresight recommendations

Foresight products should be tailored to the needs (and language, communication modes) of intended audiences. For instance, short and concise policy briefs for high-level decision-makers need to be backed up by solid analytical and exploratory reports. The use of social media for diffusing foresight results may be equally important if the wider public is the main target audience. Tailoring foresight results to specific audiences requires specific skills, for instance in terms of translating results into policy briefs.

Very often, the importance of the process of foresight is stressed as delivering additional benefits in terms of networking, mobilisation and strategic co-ordination among participants, but the process is also an important channel to facilitate the use and uptake of foresight recommendations. The participants in the process are best suited to serve as "ambassadors" of the foresight results, in particular when equipped with the right means and "products" to bring the results to bear in their own organisations (Jarmai, 2015).

Enabling the effective use of foresight in decision-making requires good embedding in the organisation (EFFLA, 2012). This embedding has several important facets, including organisational structures and responsibilities (Who is in charge?), the role of foresight in decision-making processes (When does it matter in decision-making?), the "futures literacy" of staff members in handling and interpreting foresight activities (Who is competent?) and the access to and exchange with internal and external networks/hubs of foresight knowledge (How can foresight knowledge be sourced?).

4.8 Managing a foresight process

The design and management of a foresight process needs to take into account all the aforementioned aspects, but in particular: (i) to embed foresight in decision-making structures, while maintaining intellectual autonomy; and (ii) the appropriate selection of the main approach, participants and methods. Furthermore, it is key to design and implement a communication strategy, tailored to the overall objective and the main target audience (policy-makers only versus major stakeholders, civil society organisations and the public at large).

The overall context – in particular the decision-making culture and methods, as well as the availability of the relevant methodological skills and experience – would determine (i) where to locate the management unit, and (ii) what roles and responsibilities to assign to external experts, facilitators, and foresight practitioners.

As in the case of any project financed by public funds, the operational aspects – planning an adequate budget and then respecting the financial limits, setting appropriate milestones, and keeping to deadlines – are of crucial importance. What is peculiar to a foresight process is the requirement of maintaining a certain degree of flexibility, too. In many cases, the originally identified policy needs, and hence the objectives to be served by the process, are evolving as a result of the process itself: participants arrive at a better understanding of the current situation and of future needs, opportunities and challenges on account of their intense, systematic dialogue, mobilising a diverse set of skills, knowledge, and experience. This means a careful balancing act is needed between two, somewhat contradictory requirements: to set clear objectives, on the one hand, and keep some room for flexibility, on the other, without jeopardising the timely completion of the process.

5 Main policy and organisational lessons

The systemic view of manufacturing has confirmed that successful innovation processes exploit many different types of knowledge. These pieces of knowledge are generated by various actors and activities, and hence rarely – if ever – are available inside a single organisation. It is, therefore, a major policy task to support the generation, diffusion and exploitation of all types of knowledge, as well as various types of collaborative efforts among different types of partners, across sectors, countries and world regions. The blurring boundaries between manufacturing and services reinforce this conclusion.

The cases considered above show that foresight, if applied and exploited in an appropriate way, could support policy-making at times of rapid technological and socio-economic change. It does this not only by studying how the future might evolve, but also by representing an intervention itself. With the help of participatory methods, key actors and stakeholders are mobilised to form shared views about the future, negotiate their future stakes and interests, and agree on joint and coherent actions. These benefits arise also for government, where the emergence of new challenges requires better adjustments and orchestration between different policy domains affecting emerging areas of concern or opportunity, including, among others, the new production paradigm.

To reap these potential benefits of foresight, several preconditions need to be created:

- It is essential to embed foresight appropriately in decision-making processes to make it effective. This requires changes to both organisational structures and strategy formation processes (see Box 2).
- Foresight processes need to be orchestrated with policy cycles to ensure that futures intelligence is available at the right moment in time.
- Foresight is about more than delivering a report. The participatory elements of foresight are demanding in terms of both time and resources, but they cannot be spared: the interactions among stakeholders and decision-makers are essential for triggering change processes in policy governance, society and economy.
- A sustained effort is needed to create the competences and a conducive environment for conducting foresight effectively and efficiently. One-off exercises are unlikely to yield the expected impacts on policy-making. It takes time, and possibly specific measures, to nurture and widely diffuse future-oriented thinking.
- Some form of institutionalisation – through regular programmes and/or the establishment of dedicated organisations – is needed to create a foresight culture and thus exploit its benefits in a sustained manner. As electoral cycles tend to be significantly shorter than the time horizon of the issues considered by foresight, this condition is of particular importance.
- Without intellectual autonomy in developing new insights, foresight could not fulfil its key function of pointing to major emerging challenges and opportunities and novel ways to address them.
- Context – in particular the perceived policy needs, the overall decision-making culture, and the domain to be analysed and subsequently shaped – not only matters, but is decisive when planning and conducting a foresight process. A general blueprint for devising and running a foresight process, therefore, would not fit anyone's needs. Learning from experience of others is highly beneficial, but it would be a great mistake to search for a "one-size-fits-all" guide or copy any country's practices, regardless of how successful a certain methodological and organisational model has been in that country.

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