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Orienting European innovation systems towards grand challenges and the roles that FTA can play

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A strong research and innovation policy discourse has emerged in recent years around the need to address 'grand challenges', particularly at EU level. This paper highlights the contributions that future-oriented technology analysis (FTA) might make to orienting innovation processes towards grand challenges. It takes a 'systems of innovation' approach and focuses on the structural and functional aspects of such systems to consider the relevant roles of FTA. In this context, FTA can generate 'informing', 'structuring' and 'capacity-building' benefits while enabling a shift in innovation foci towards grand challenges. However, FTA could be better exploited to deliver its structuring and capacity-building benefits, which are hardly recognised in the EU's existing innovation policy instruments, in order to effectively reorient the EU's innovation systems towards grand challenges.

Keywords: innovation systems; grand challenges; european union; foresight; technology assessment.

1. Introduction

Recent years have seen a great deal of discussion on how science, technology and innovation (STI) systems might be reoriented to better address several grand challenges that affect not only contemporary societies but also the future of human civilisation itself. This is part of a new mission-led approach to innovation policy that is more global in outlook and oriented towards more societal goals. It differs from an earlier mission-led period (1940s and 1950s) that was more nationally focused and largely oriented towards supporting the military–industrial complex (Gassler et al. 2008).

The issues covered by the term 'grand challenges' naturally lend themselves to a global outlook, are grand in scope and scale, and are generally made up of 'wicked problems' (Rittel and Weber 1973) that are difficult or even impossible to solve by single agencies or through rational planning approaches. This has been well-understood for some time among academics and activists and the articulation of such grand challenges is hardly novel. The main novelty lies in the increasing attention given to such issues in formulating new missions for STI policy. The reasons for this are complex: in part, they reflect a perceived growing urgency to address a series of problems that could, if neglected, have catastrophic consequences on a global scale over the next few decades. But they also reflect a more overt steering of STI efforts—at least those funded by the public purse—to meet explicit political goals.

This new orientation is perhaps nowhere more in evidence than at the EU level, where grand societal

challenges are presently a major focus of research and innovation policies. The aim is to rejuvenate the European Research Area (ERA), an overt political project, which, since its adoption a decade ago, has yet to meet the expectations of European policy-makers. It is hoped that the agreement and articulation of grand challenges at the EU level will mobilise Member States to better synchronise their STI policy instruments, including public procurement, regulation and direct R&D funding, thereby contributing to the realisation of a fully fledged ERA.

However, these efforts face many practical and conceptual hurdles. Grand challenges are by nature complex and largely impervious to top-down rational planning approaches. Even their meanings tend to be highly contested by different actors. Furthermore, any attempts to address them must span a number of long-standing organisational, epistemic and sectoral boundaries, requiring, for example:

- Interdisciplinarity that transcends the boundaries of traditional epistemic communities. Addressing grand challenges requires the pooling of different knowledge bases and, in particular, closer collaboration between the 'hard' and social sciences and humanities.
- Cross-departmental coordination and coherence beyond the traditional silos that characterise policy-making. Grand challenges require multi-agency responses and it is important that these are coherent if they are to be more or less effective.
- Multi-level governance approaches that acknowledge the principle of subsidiarity while ensuring coherence between global, regional (e.g. European), national, and sub-national agendas and activities to address grand challenges.
- Technology convergence or fusion that opens up new possibilities to manage, mitigate or even eliminate some of the causes and harmful symptoms associated with grand challenges.
- Cross-sectoral collaboration between various industries with the complementary assets to address grand challenges.
- Longer-term time horizons to be introduced more explicitly into shorter-term policy agendas and business planning practices.

If grand challenges are to be operationalised as rationales for STI policy interventions, the need to transcend these boundaries should be widely appreciated, as should the dynamics of research and innovation processes and the scope and opportunities for steering their reorientation along more desirable pathways of development. In this regard, it is important to recognise that innovation can just as much exacerbate the problems associated with grand challenges as it can contribute to their solutions. The STI agenda around grand challenges must therefore be about much more than just end-of-pipe technological fixes. Rather, STI agendas should seek to better orient innovation activities along more sustainable pathways that enable positive transformations of socio-technical systems and that lessen the conditions that allow adverse developments to occur.

Certain traditions in the FTA family of approaches, particularly technology assessment, have taken the reorientation of technological trajectories and innovation activities as an explicit goal. But the impacts of FTA in this respect have fallen somewhat short of expectations up until now. The central question in this paper is whether or not the new mission focus on grand challenges offers windows of opportunity for a more directed and positively transformative innovation practice to develop, and if it does so, the supporting roles that FTA might play, especially in relation to newly established EU instruments.

Reflecting the above considerations, this paper starts (Section 2) by presenting the basic elements of innovation and the need for an operational agenda that takes into consideration a context-sensitive approach required to address specific challenges. Section 3 describes the working of innovation systems around their structural elements focused on actors' capabilities, the scale and nature of system interactions, and the working of institutions, and their dynamic functions of experimentation and learning, knowledge development, knowledge diffusion, guidance and the selection of options, market formation, and mobilisation of resources. This is followed by a discussion (Section 4) of the systemic reorientation of innovation systems towards grand challenges and the demands put on policy and governance. Section 5 then explores the roles of FTA in enabling a shift in innovation foci towards grand challenges. This relates to FTA's informing, structuring and capacity-building benefits, which are transposed onto specific contributions to innovation system functions. Section 6 discusses the associated implications for international EU research and innovation collaboration, the degree to which recent developments cover the identified needs in the reorientation and governing of innovation systems and STI policies, as well as the contributions FTA could make to orienting policy agendas towards grand challenges. Section 7 draws some conclusions.

2. Innovation: Some essentials

If innovation is to contribute to solving some of the grand challenges of our time, it is important to set out some sort of baseline as to what it is, how it is practiced and by whom, and the reasons or conditions for it to occur. In other words, it is important to move beyond the often glib political statements of the importance of innovation for grand challenges and towards an operational agenda that appreciates both the dynamics of innovation processes and the scope and opportunities for their steering or reorientation along more desirable paths of development.

Innovation refers to a process of introducing a new product, process, service or organisational form into the marketplace and the social sphere (OECD and Eurostat 2005; Fagerberg et al. 2004). It occurs mostly in firms that respond to expected market opportunities by combining different types of knowledge, capabilities, skills and resources (Hall and Rosenberg 2010). Expectations of such opportunities can be created by any number of factors, many of them defined differently in different national spaces, e.g. through regulations, financial incentives, consumer preferences etc. This suggests there are many potential levers for shaping the direction of innovation towards grand challenges. At the same time, innovation is a systemic phenomenon by nature as it results from the continuing interaction between different actors and organisations (Freeman 1970). This means that a firm does not innovate in isolation but rather in interaction with its environment. Such environments are complex by nature and difficult, indeed, mostly impossible, to shape with a view to directing innovation in a predictable top-down manner. This has implications for any attempts at guiding innovation activities towards grand challenges.

Innovations can be radical and disruptive but often result from a long process involving many interrelated innovations (Rogers 1995; Freeman and Soete 1997). Furthermore, many economically significant innovations occur while a product or process is being diffused since the introduction of something 'new' in a different context often implies adaptation and technology transfer and/or organisational changes (Hall and Rosenberg 2010). This incrementalism often leads to lock-in and path-dependency along technological trajectories that can be difficult to escape, even if a consensus exists that alternative trajectories would be more beneficial to follow. Such lock-in has to be borne in mind when linking innovation agendas to grand challenges as it will likely act as a barrier to the radical changes that are probably needed.

It is also important to highlight that the factors influencing innovation differ across industries, and this has implications for policy (Fagerberg et al. 2004). Factors vary, for instance, on R&D intensity (i.e. high-tech, medium tech and low tech) and on issues such as availability (or the possibility to develop) skilled labour, a culture of learning by doing, ways and intensity of interacting within and beyond the sector, business routines as well as organisational and institutional patterns and infrastructures, finance available (including foreign direct investment), public procurement, standards, intellectual property rights, regulations etc. This highlights the fact that a one-size-fits-all approach to promoting innovation is unlikely to work across the range of grand challenges to be addressed. Rather, a more nuanced and context-sensitive approach will be required that takes into account the nature of each challenge and the industries and sectors that need to react and that will be affected.

3. Innovation systems and their functioning

Thus, innovation can be understood as a systemic activity, with firms and other innovating actors operating in linked environments of institutions and other actors. In this view, national innovation systems are complex constructs, displaying a variety of structures in a range of contexts and performing various functions. The advantages of thinking in terms of innovation systems is that they provide a more complete picture of the topography of innovation-relevant actors and the relations between them, which are patterned by institutions that are nationally- and sectorally-specific (including 'hard' institutions like law, but also 'soft' institutions like trust). There are distinct differences in actors and relations-shaping institutions between countries and sectors, and in the way they perform. This means there is no possibility of a one-size-fits-all policy mix to improve the performance of innovation systems.

Innovation system analysis often takes as its starting point the system's structure. It is here that innovation system failures that demand policy attention tend to be identified, focused around actors' capabilities, the scale and nature of system interactions, and the workings of institutions (Arnold 2004; Woolthuis et al. 2005). Indeed, expected system elements might be completely absent in some national settings—particularly in less developed countries—and/or weakly developed or dysfunctional in others. Each of these structural elements is further described below:

- Actors: these include a wide range of types of organisation, including: firms (large and small, multinational and domestic), universities, public research labs, government ministries and agencies, and intermediary bodies, such as industry associations and private consultants. In many innovation systems, such organisations are either missing or are weakly developed, thereby hindering system performance. An organisation's history, culture and memory are expressed in its missions, values and routines. These contribute to its dynamic capabilities, which are unique to each organisation and are technical and organisational in nature. Any reorientation of innovation systems towards grand challenges is likely to require both the establishment of new organisations and the adaptation of existing ones.
- Interactions: cooperation and interactive learning are central to the process of innovation. Such interactions involve not only firms (though these are more common), but also universities, government labs, ministries and funding agencies, among others. Weak interactions are commonly diagnosed as problems

for innovation systems, since cycles of learning and innovation are less likely to become established when system connectivity is poor. However, higher levels of interaction need not necessarily be better for innovation system functioning either. This is because strong cooperative relationships can lead to over-embeddedness, marked by myopia and inertia (Woolthuis et al. 2005). Hence, when innovation systems need to be reoriented, a lot of unlearning and disruption of existing linkages will be required as part of the processes of transformative change.

- Institutions: these constitute the rules of the game and codes of conduct that reduce uncertainty in the innovation system. Institutions are emergent, in that they are generated by the activities of actors and their interactions with one another. At the same time, they also structure these activities and interactions. Distinction can be drawn between hard institutions (e.g. formal written laws and regulations) and soft institutions (e.g. social norms and values) that can enable or hinder innovation. Generally speaking, institutions provide important levers for policy to shape actors' behaviours and interactions. This makes them an essential starting point in efforts to set in motion virtuous cycles of transformative change directed at grand challenges.

Extending the heuristic construct of systems of innovation, some authors (e.g. Bergek et al. 2008) have recommended the functions of innovation system as an alternative point of analytical departure.[1] Such functional analysis, which is intended to supplement rather than substitute for more traditional structural analysis, implies a focus on the dynamics of what is actually achieved in an innovation system. This is a potentially useful perspective for efforts directed at reorienting innovation systems towards grand challenges.

Drawing upon a mix of sources (Bach and Matt 2005; Bergek et al. 2008; Edquist 2008; Hekkert et al. 2007; Jacobsson and Bergek 2006; van Lente 1993; von Hippel 2005; Woolthius et al. 2005), the following six 'high-level' functions of innovation systems can be identified:

- Facilitate experimentation and learning: safeguarding 'variety' in the innovation system is key given the uncertainties that follow from new combinations of knowledge, applications and markets. Entrepreneurial experimentation reduces uncertainty through a continuous probing into new technologies and applications that allows many forms of social learning to take place.
- Nurture knowledge development: this is considered to be the most basic function of innovation systems without which nothing else would happen. It has traditionally been associated with R&D, but there are different types of knowledge besides science and technology knowledge, including production, design and market knowledge. The sources and locations of knowledge development are wide-ranging, and include R&D activities in the public and private sectors, and design and production in firms.
- Promote knowledge diffusion: given the distributed nature of knowledge production, knowledge diffusion is an essential function of innovation systems. Diffusion may be mediated through networks—for example, between industry and academia or between firms in a business cluster—but also commonly occurs through more market-based mechanisms, such as user–producer interactions and supply chains. Standards, design protocols, production manuals, among others are further mechanisms.
- Guide direction of search and selection: given that resources are finite, it is important for innovation systems to be able to guide actors in selecting options for investment. A number of mechanisms contribute to this guiding function, including: various visions and expectations, regulations and policies, and the activities of lead users. As such, guidance can be considered to be an interactive and cumulative process of exchanging ideas between technology producers, users and many other actors.
- Promote market formation: markets often do not exist or are weakly developed, particularly for radical innovations. The innovation system therefore needs to create spaces, for example, through procurement policies, standards or regulations that nurture demand for innovations.
- Develop and mobilise resources: an important function of innovation systems concerns the development and mobilisation of human resources, financial capital and complementary assets (e.g. infrastructures). These can be developed in a number of settings: for example, human resources are developed not only in colleges and universities but also in firms. The mobilisation of resources has important consequences for knowledge development activities.

4. Orienting innovation systems towards grand challenges

The special nature of the requirements of grand challenges to find effective solutions brings to the fore concepts such as transformative (in radically changing unsustainable current practices), responsible (going beyond profit and economic competitiveness to safeguard social and environmental goals), and social (for the public good) innovation (Depledge et al. 2010). Furthermore, grand challenges cannot be effectively dealt with through technological innovations alone. They require broader changes in human perceptions and behaviour, as well as social innovations promoting non-technological solutions. The challenge is for business, governments and societies to align and

evolve into this new direction, identifying alternative solutions and moving away from the current state of affairs.

The structural and functional elements of innovation systems presented above highlight sites for exploitation and intervention in support of grand challenges. Specifically, the structural elements—particularly the institutions—point to mechanisms for enacting change through intervention while the functions signpost the sorts of issues that must be addressed if innovation systems are to be oriented towards grand challenges.

Starting with the structural elements, the global character of grand challenges and their boundary-spanning nature: which sees them transcend both epistemic and administrative boundaries, implies a greater number and wider variety of actors involved in innovation systems. Indeed, right at the outset, a more transformative innovation sets a responsibility to catalyse and facilitate more effective public dialogue beyond the usual suspects by engaging new entrants, small business, wider stakeholders and civil society. Interactions are potentially more numerous as a result, offering more opportunities but also creating more complexity and reducing the scope for top-down steering.

The institutions that pattern actors' behaviours and interactions are also more variable and likely to operate in less than predictable ways as they span traditional boundaries. Changes in soft institutions are likely to be particularly critical in determining progress in finding viable paths towards tackling grand challenges and any consequent change in paradigms that these may entail. This is especially relevant for certain challenges like those related to environment and natural resources. Finding a solution to the problem of scarce energy resources, for example, requires not only surpassing long-established vested interests in certain resources but also a change in the behaviour, norms and values of societies.

Other changes required in soft institutions concern the motivations and focus of business actors in engaging with innovation, since certain grand challenges call for social responsibility and a business focus beyond a mere return on investment and greater orientation towards the public good. This change is reflected in terms such as: corporate social responsibility, corporate citizenship, or stakeholder theory, in which business organisations increasingly promote innovation in their social and environmental policies (Smith 2000). It is an emergent trend encouraging activities that generate mutual benefit to business and society or the natural environment (Bright et al. 2006). Non-profit making motivations have also already surfaced in trends towards commons-based peer production (Benkler 2006). This so-called social production, may exercise a significant force on the shape and conditions of market action if a newly effective form of social behaviour is coupled with a cultural shift in tastes which may lead to solutions found or devised by collaborating individuals rather than market-based firms.

Turning to the functions of innovation systems presented earlier, Table 1 uses these to map a number of actions conducive to systemic reorientation towards grand challenges. The key challenges lie in engaging different voices, protecting spaces, balancing vested interests, making connections, coordinating experiments, levering investments, facilitating learning and informing expectations. In this regard, there is a need for additional policies that are related to networks, community building, visions, experiments and learning. Such socio-technical approaches refrain from simple policy recipes. Instead, they highlight co-evolution, multi-dimensionality, complexity and multi-actor processes, conditions that, it will be argued below, are intrinsic to FTA (Cagnin et al. 2008). At the same time, appropriate constellations of policy interventions will vary, depending on specific challenges, opportunities and problems encountered in sectors, technologies and social networks (Stirling et al. 2009).

Clearly, the eorientation of innovation systems places particular demands on STI policy and the governance of innovation systems. Boden et al. (2010) highlight the need for the creation of more transparent and accountable forms of governance that are better able to anticipate and adapt to the future and thus address common challenges, and to spread democracy and transparency at the global level. In this regard, FTA as a tool of governance could have a promising role to play in reorienting innovation systems towards grand challenges.

5. FTA for orienting innovation systems towards grand challenges

Th paper takes FTA to refer to systematic processes of strategic foresight, forecasting and technology assessment. These are future-oriented processes that offer policy- and decision-makers the potential to look across (disruptive) transformations which are either required as a solution to or caused by grand challenges. Crucially, at least from the perspective of transcending boundaries to better address grand challenges, FTA processes bring longer-term perspectives and broader knowledge bases into decision-making processes. By doing so, they place greater emphasis on holistic and multiple perspective approaches under which many potential levers for shaping the direction of innovation can be identified (e.g. regulatory, financial, consumer behaviour etc.). They can also assist in managing the uncertainty associated with innovation activities and with the future more broadly by providing spaces for policy, business and societal actors to come together to better appreciate their mutual positions *vis-à-vis* future innovation directions. From a policy arena perspective, this coordination potential can enhance communication and understanding

Table 1. Innovation system functions and their reorientation towards grand challenges

	Reorientation towards grand challenges
Facilitate experimentation and learning	Solutions to grand challenges will require, in many instances, radical socio-technical innovations. Experimentation and learning needs to be strengthened, with greater amounts of probing and experimentation in areas that are potentially relevant to grand challenges. This can be facilitated through, for example, research and innovation programmes
Knowledge development	Transformative shifts implied by solutions to grand challenges will need new knowledge as well as a new type of knowledge production. New knowledge (including also non-technological knowledge) has to be developed on topics relevant to grand challenges among a distributed landscape of actors. This implies a type of knowledge production close to the so-called 'mode 2' (Nowotny et al. 2003) acknowledging the distributed nature of knowledge, and facilitating knowledge creation across different boundaries at various levels (as explained in Section 2)
Knowledge diffusion	Knowledge diffusion is essential given the boundary-spanning nature of grand challenges. The need for cross-disciplinary/departmental/national/sectoral coordination implies new channels for knowledge diffusion among actors that have traditionally worked apart
Guide direction of search and selection	Dealing with grand challenges requires strong visions, strong in the sense that they constitute mobilising convictions among a large group of actors. These should be socially-embedded and guiding lights for businesses, policy makers and consumers. Building these visions should be an inclusive, joint process, highlighting inter-dependencies and encouraging alignment of actors. The incompatibility of existing visions which have lead to unsustainable solutions also has to be addressed in this process
Create spaces for market formation	Market formation means generating protected spaces for the supply side to experiment and learn (see function 'Facilitate experimentation and learning' above) but also for the demand side to be developed. This can be done through a mix of regulation, procurement and other market-creating incentives
Develop and mobilise resources	The development and mobilisation of new resources translates into new skills (or reorientation of existing ones) and the reallocation of financial resources. There is a need for forums/spaces for advocacy coalitions to emerge and be mobilised: this is especially important given the boundary-spanning nature of grand challenges

between policy 'silos' and thereby support the emergence of an effective policy mix for innovation. Finally, the act of participating in FTA processes can itself be transformative by encouraging the adoption of new perspectives and the development of new capabilities to detect and process signals of future change. In this way, FTA processes can enable governments and other actors to become more adaptive and capable of enacting systemic change.

Thus, FTA can play a number of important roles (see Fig. 1) in orienting innovation systems so that they can better address grand challenges. These roles can be grouped under three main headings: informing decision-making processes, structuring and mobilising actor networks, and capacity-building among innovation system actors. Fig. 2 illustrates the inter-relatedness of these FTA roles with the innovation system functions outlined earlier in the paper (see Table 1). The inter-relations are summarised in the sub-sections that follow.

5.1 Informing decision-making

The informing role of FTA most closely relates to the innovation system functions of facilitating experimentation and learning, knowledge development, and directing search and selection. For example, FTA processes can inform policy-making by providing spaces for experimentation where a quest for new solutions and changes in paradigms is needed. At the same time, FTA processes place a special emphasis on novelty, creativity and multi-disciplinarity in knowledge development, qualities that are needed when exploring the nature and impacts of grand challenges as well as their possible solutions. The knowledge developed under FTA helps to articulate visions and expectations which can form the framework under which to examine possible solutions to specific challenges. In this way, FTA processes inform and direct the search and selection of possible solutions.

5.2 Structuring and mobilising actor networks

The structuring role of FTA relates to the aim of identifying and bringing together diverse actors and stakeholders and creating spaces for discourse and joint action. FTA processes have a long tradition of creating spaces for dialogue and for engaging different actors to confront views, learn from one another, and agree on a path to follow that usually includes broader and more comprehensive options than would otherwise have been the case (Cagnin et al. 2008). This role most closely corresponds to the innovation functions of knowledge diffusion, mobilisation of resources, and creating spaces for market formation. FTA processes lead not only to new combinations of

Some common uses of FTA

Informing decision-making processes

- ✓ Formulate funding and investment priorities for public policies
- ✓ Evaluate existing strategies against potential futures, and devise future-proof strategies
- ✓ Develop reference material for policy-makers and other actors to use, broadening the knowledge base around which decisions are made, thereby resulting in better informed public policies or organisational strategies
- ✓ Provide anticipatory strategic intelligence to innovation system actors, including overall citizens, thus leading to policy processes amenable to current and future issues
- ✓ Detect and analyse weak signals to 'foresee' likely future changes and to gain insights into complex interactions and emerging drivers of change
- ✓ Identify new S&T, business, societal, policy and political opportunities
- ✓ Increase awareness of possible risks, and hence the basis for more effective contingency planning, and the design and development of appropriate forms of resilience

Mobilising and structuring actor networks

- ✓ Improve implementation by enabling transparency, legitimacy and buy-in to decision-making processes
- ✓ Increase public awareness and stakeholders' understanding of different viewpoints, thus contributing to the building of shared agendas and dynamic multilateral partnerships
- ✓ Develop widely shared visions of the future with which actors can identify and thereby better co-ordinate their activities, be they individuals or organisations
- ✓ Disrupt 'lock-in' thinking and challenge fixed mindsets
- ✓ Aid communication, understanding and collaboration across boundaries, be they geographical, organisational or disciplinary in nature
- ✓ Deepen dialogue with society and improve governance, thus increasing trust between policy makers, business and the general public and consequently reducing the number of occasions when products and services based on new technologies are rejected

Creating new capabilities

- ✓ Improve decisions by meeting societal expectations and avoiding the assumption that people have infinite plasticity towards new technology
- ✓ Enhance strategic capabilities of organisations by helping to develop a language and practice for thinking about the future – something that is often termed a 'foresight culture'
- ✓ Enhance the standing and image of organisations using FTA, showing them to be future-oriented and open, and attractive places for investment
- ✓ Enhance responsiveness of organisations by supporting change in individuals' behaviour and helping these to steer solutions to emerging challenges through joined-up decisions, thereby enabling the system to undertake systemic transitions and new configurations

Figure 1. Some common uses of FTA.
Source: Adapted from Barré and Keenan (2008) and Cagnin et al. (2011).

knowledge but also to new combinations of actors that are mobilised to fulfil the promises articulated in guiding visions, such as those around the means to tackle grand challenges. More broadly, FTA can raise awareness and sensitise society towards sustainable solutions, while also bringing public concerns and interests into the debates. The collective knowledge creation enabled by the structuring role of FTA processes enables the articulation of market-shaping expectations and visions, which contribute to creating spaces for market formation.

5.3 Building organisational capacity

The capacity-building role of FTA refers to the enhancement of strategic capabilities and the responsiveness of individuals and organisations to emerging challenges via the adoption of forward-looking, collaborative routines and practices. This capacity-building role sees FTA processes potentially contributing to all innovation system functions by directly affecting the mind-sets and attitudes of individuals and the routines and capabilities of organisations. By doing so, FTA processes support organisational and societal agility through the anticipation of developmental routes and their consequences, and/or the articulation of widely shared visions that steer evolutions along desirable pathways. This might involve thinking out of the box and challenging mind-sets, which can be crucial for identifying and understanding future solutions that run counter to mainstream practices. This can be a first step in trying to overcome certain lock-ins and path-dependencies along specific socio-technical trajectories.

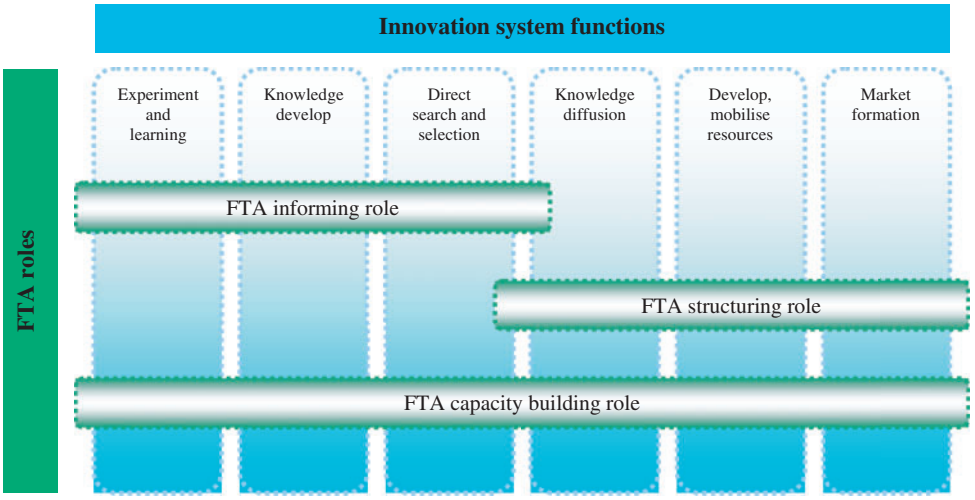

Figure 2. Contributions of FTA roles to innovation system functions.

6. Implications for European collaborative programmes

This section examines some of the recent STI policy initiatives of the EU that seek to better orient policy agendas towards grand challenges and considers the contributions that are being, and could be, made by FTA in this regard. In general, having to deal with more global issues implies a corresponding organisational capacity to deal with them and an ability to respond at the international level. Hence, there is a potentially important role for international organisations to play in this regard.

Addressing grand challenges is at the core of EU policies for research and innovation as illustrated by the latest EU strategic policy documents. The Europe 2020 Strategy[2] is explicitly oriented towards tackling grand societal challenges and has formulated ambitious policy objectives for climate change, energy security, demographic ageing and resource efficiency. At the same time the Europe 2020 Strategy notes that a partnership approach should extend to EU committees, to national parliaments and national, local and regional authorities, to social partners and to stakeholders and civil society so that all main stakeholders can be involved in delivering on the vision of Europe 2020. At the same time, the Innovation Union[3] Flagship Initiative recognises that the same challenges also provide powerful opportunities to develop innovative products and services, creating growth and jobs in Europe. In this regard, it advocates a strategic and integrated approach to research and innovation in dealing with grand challenges while also strengthening European competitiveness.

However, it is generally agreed that existing policy implementation tools for STI cooperation fall short of adequately supporting broad-based collaborative action at the scale and intensity required to tackle grand challenges. Current EU programmes fall short in attracting and engaging certain stakeholders like businesses (Annenberg et al. 2010), as well as in contributing to the coordination of national and local research and innovation policies towards joint goals (IDEA Consult 2010). Additionally, there are limitations to achieving the necessary flexibility, creativity and cross-disciplinary research needed to tackle grand challenges, although this may be true to different degrees across the different research themes.

These shortcomings are well recognised in Horizon 2020 and certain new initiatives have been proposed to overcome them. The following relatively new initiatives can be highlighted which are explicitly focusing on grand challenges.

The Joint Programming Initiatives (JPIs) have been put forward as the main means for coordinating national and regional efforts towards commonly set research agendas and visions. To date, joint programming has been implemented through schemes like the ERA-NET, ERA-NET PLUS and Article 185.[4] JPIs go beyond existing relevant schemes by implementing joint research programmes towards real public-to-public partnerships between Member States and the EU (ERAC-GPC 2010).

The concept of European Innovation Partnerships (EIPs) introduced by the Innovation Union Flagship Initiative is the overarching framework embracing relevant joint programming activities ranging from Art. 185 initiatives to ERA-NETs, or JPIs. EIPs give particular emphasis to the engagement of the business sector. EIPs focus on innovations that address major societal challenges and pursue a broad concept of innovation involving all actors and regions in the innovation cycle, i.e. large firms, small and medium-sized enterprises, the public sector, the social economy and citizens themselves (CEC 2010). The concept of the EIPs is wider and placed at a more generic level than existing initiatives like JPIs, or Art. 185 initiatives (Wintlev-Jensen, cited in Amanatidou 2011).

The Knowledge and Innovation Communities (KICs) initiative introduced by the European Institute of Innovation and Technology, is another form of research public–private partnership (PPP), again placing considerable importance on the engagement of the business sector. KICs cover the entire innovation chain, and bring together partners from research, business and academia to work together on major societal challenges.

At the same time, certain 'old' initiatives have become relevant in dealing with grand challenges. These initiatives reflect the importance put on linking research to innovation and creating viable PPPs, which is a long-standing feature of EU research and innovation policies. In particular the Joint Technology Initiatives (JTIs),[5] having evolved from European Technology Platforms,[6] are accommodating a strong interest from industry to address major challenges. In the same vein, three PPPs were established under the European Economic Recovery Plan to help industries that were hit severely by the economic recession (Factories of the Future, Energy Efficient Buildings and Green Cars).

The new instruments mentioned above have only started recently, so any comprehensive assessment of their use and application of FTA would be premature. However, their scope and focus acknowledge the boundary-spanning nature of grand challenges. They clearly highlight the inter-disciplinarity needed in the knowledge bases that have to be combined in searching for possible solutions and examining developments and possible implications. By promoting the inclusion of all relevant stakeholders they can facilitate cross-sectoral collaboration between the public and private sectors as well as between various industries, a multi-level governance approach, as well as cross-departmental policy coordination and coherence.

The new instruments also acknowledge the importance of long-term time horizons to be introduced more explicitly into shorter-term policy agendas and business planning practices. FTA has already played some role in the old instruments, e.g. in setting the strategic research agendas in ERA-NETs and the European Technology Platforms, and lately also in the KICs. A brief scanning of their deliverables shows that the use of FTA varied from one project to another. Overall, however, FTA was used as a means for setting directions and priorities through knowledge development based on expert knowledge and by mobilising the resources available in the actors already involved in the projects. In this regard, the old instruments mainly exploited the informing role of FTA.

FTA also has a role to play in the new instruments. The identification of grand challenges and the corresponding priorities for research and innovation through the use of forward-looking activities is explicitly mentioned in the Council's conclusions (December 2009)[7] on guidance on future priorities for European research. In fact, foresight activities is one of the six joint programming framework conditions[8] for which analytical guidelines are developed to facilitate the planning and implementation of joint research programmes (ERAC-GPC 2010). The importance of trans-national foresights is also specifically highlighted for joint programming (Acheson et al. 2007).

In this regard, the importance of the informing role and benefits from FTA are already recognised in the new instruments. Especially in relation to knowledge production, the role of FTA is seen to be important for encouraging the multi-disciplinarity needed both in terms of research focus as well as in the identification of policy implications given the interdependencies of grand challenges and the wide range of policy areas that are involved.

Nevertheless, FTA could also play other potential roles in the new instruments dealing with grand challenges through better exploitation of its structuring and capacity-building roles, which are equally important in dealing with grand challenges although hardly recognised. With regards to its structuring role, FTA could be useful in facilitating experimentation and learning, since providing experimental spaces for new ideas to emerge and develop will be crucial in trying to find novel solutions to grand challenges. Such a role could be accommodated in the stages of shaping a common vision for the selected theme or challenge at hand, in defining a common strategic research agenda, and in implementing a jointly defined strategy (e.g. initiating risky but possibly high-return projects, funding a variety of competing technologies etc.). The methods applied should promote expertise and experience but also creativity. These spaces could also be created at different levels of governance (regional, national, EU) under a coordinated approach (through joint programming for example) to ensure the coordination and complementarity needed in regional, national and EU-level efforts to tackle grand challenges.

Additionally, the role of FTA in developing and mobilising resources becomes relevant in identifying the most relevant actors and stakeholders to engage so that forums or spaces for advocacy coalitions can emerge and be mobilised considering all relevant stakeholder groups. This role could be enabled in a step prior to setting the governance structures and bodies of the instruments to be created. For instance, the identification of suitable actors to engage can take place by mapping stakeholders based on certain criteria and paying attention to relevant gaps or stakeholders which, although concerned with the issue at hand, are usually not involved in any sort of debate. By bringing together relevant stakeholders, EU instruments can be a means to enable different parties to learn with one another and identify knowledge gaps (leading to new or reoriented skills) as well as to the identification of potential financial resources. In its role in knowledge diffusion, FTA can enable a range of communication

Table 2. FTA roles in innovation functions and their integration in EU instruments

Innovation system function	FTA roles	Integration of FTA in EU instruments
Facilitate experimentation and learning	FTA can provide 'safe spaces' for new ideas to emerge and for existing knowledge to be combined in novel ways. Such experimental spaces can occupy multiple positions in systems of multi-level governance, i.e. FTA can be performed at different levels and in different places, thereby contributing to the creation of variety in innovation systems	Informing role of FTA facilitates building of a common vision for a specific theme or challenge, and in defining a common strategic research agenda amongst involved stakeholders Capacity building role of FTA supports stakeholders to engage, exchange ideas and explore and create solutions to situations or challenges at hand
Knowledge development	FTA, as a source of 'strategic intelligence' for policy and other actors, is itself a knowledge-creating activity. It can, for example, provide insights into longer-term developments, scope and opportunities for shaping futures, and mutual positioning of other innovation system actors *vis-à-vis* the future. In addition to these, FTA processes can encourage multi-disciplinarity in research needed when exploring the nature and impacts of grand challenges as well as their possible solutions	Informing role of FTA can be embedded within EU instruments in the steps of challenge/problem identification, prioritisation of associated themes and areas for research, and setting strategic research agendas Capacity building role of FTA supports building skills for engaging in multi-disciplinary teams and applying a forward looking approach to situation/challenge at hand
Knowledge diffusion	FTA involves bringing together often disparate actors that might not normally interact to imagine and debate possible and desirable futures. In this way, FTA provides forums for knowledge to be exchanged and created. At the same time FTA can raise awareness and sensitise society towards sustainable solutions, while also bringing public concerns and interests into debates	Structuring role of FTA can be enabled within EU instruments when defining priority areas of common interest and in setting strategic research agendas among different actors Capacity building role of FTA supports collective learning and knowledge creation
Guide direction of search and selection	FTA tends to lead to articulation of visions and expectations that guide actors in their search and selection of future opportunities. It is perhaps the main rationale offered for conducting FTA as a means for setting directions and priorities	Informing role of FTA can be embedded within EU instruments in the steps of challenge/problem identification, and prioritisation of associated themes and areas for research Capacity building role of FTA supports diverse expectations to be framed when developing joint visions and understanding their long-term implications
Create spaces for market formation	FTA's contribution to market formation tends to be more indirect, for example, through articulation of market-shaping expectations and visions and conditions for coordination of market actors that these provide	Structuring role of FTA allows consideration of future market applicability of different alternatives alongside with research excellence needed to foster their development Capacity building role of FTA supports articulation of market-shaping expectations and stakeholders' visions, and in coordinating actors
Develop and mobilise resources'	FTA processes lead not only to new combinations of knowledge but also to new combinations of actors that are mobilised to fulfil the promises articulated in guiding visions. Even where new actor networks have not emerged, the FTA process and its products can mobilise those involved to reassign resources	Structuring role of FTA enables definition of governance structures and bodies Capacity building role of FTA supports teams of diverse actors to engage and join forces for designing common desirable futures

channels that allow cross-disciplinary coordination and learning between diverse and often disparate actors to take place, which ultimately supports the achievement of the inclusiveness claimed to be needed in dealing with grand challenges. This should be accommodated in selecting priority areas for research as well as in setting strategic research agendas. Finally, the role of FTA in creating spaces for market formation, by means of articulating market-shaping expectations and visions could be utilised when setting the common strategic research agenda as well as in the implementation phase with equal consideration of market applicability and potential alongside research excellence.

Last, but by no means least, the capacity-building benefits of FTA should not be neglected. Enhancement of the strategic capabilities of individuals and organisations through the development of a foresight culture can be an important side effect of any FTA activity, provided appropriate provisions are made in the design of the new instruments. Such provisions may involve, among others, a well-organised preparation phase including training and enabling trust building, as well as regular interactions among stakeholders that allow active engagement and understanding of foresight philosophy and practices.

Table 2 summarises the ways FTA could be integrated into some of the EU instruments discussed above and the

contributions these would make to various innovation system functions.

7. Conclusions

This paper has outlined the contours of an emerging mission-led approach to innovation policy that is more global in outlook and oriented towards so-called grand societal challenges. It has argued that a reorientation of innovation systems towards grand challenges could offer opportunities for a more responsible and transformative innovation practice to develop. But it has also highlighted the boundary-spanning scope of grand challenges and the difficulties this implies in mobilising actors and resources for enacting transformative change. A different type of innovation policy is essentially required that better acknowledges the co-evolutionary, multi-dimensional, complex and multi-actor nature of the processes involved in enabling transformative change.

In this context, this paper has introduced some of the contributions that FTA could make to orienting innovation systems towards grand challenges. In the first instance, FTA can lead to the generation of new knowledge or novel combinations of existing knowledge that can inform formal decision-making and priority setting processes. This can be thought of as the information role of FTA. Taking a systems of innovation approach, the paper also suggests that FTA can support the spanning of traditional boundaries that might otherwise act as barriers to progress on addressing grand challenges. In this sense, it can perform a more structuring role for innovation systems in need of reorientation. For example, FTA can enable spaces for dialogue and interactions between actors to emerge, which can lead to the establishment of new linkages (as well as the disruption of existing ones). More than creating spaces for sharing ideas alone, FTA can foster experimentation and learning, and allow decisions to be shaped within wider settings through new inclusive and participatory governance approaches. With regards to its capacity-building role FTA can contribute to the articulation of strategic visions that can guide search and selection processes, thereby reducing some of the uncertainties that traditionally characterise innovation-related processes. Finally, the ability to conduct and/or utilise FTA is itself a valuable dynamic capability that encourages organisations to be more responsive, adaptable, and open to change.

Current EU programmes and initiatives mainly exploit the informing role of FTA in knowledge development and in providing guidance for direction or prioritisation of research areas and themes. In this context, however, the potential to engage diverse stakeholders enabled through FTA does not always take place. Ultimately, decisions are still somewhat top-down. With very few exceptions[9] the design of or decisions around such programmes neither foster the creation of spaces for experimentation and learning, nor allow for new knowledge to be developed or diffused as usually, very few actors (usually termed experts) take part in the dialogue or creative process.

The structuring role that FTA could provide and where much benefit might be obtained, in effectively orienting innovation systems towards grand challenges remains under-exploited. One rectifying step would be to better consider the structural and functional aspects of innovation systems with a view to identifying bottlenecks and appropriate points for effective policy intervention. A promising framework for this purpose is offered under the concept of JPIs for example. As acknowledged in the Voluntary Guidelines on Framework Conditions for Joint Programming in Research 2010[10] forward-looking activities might be used both when identifying grand societal challenges as well as in translating an already identified grand challenge into an operational reality by defining scenarios, which decision-makers could then use to underpin their choices, by defining strategic research agendas, and by providing recommendations on the available alternatives. In the latter case decision-makers should work together with specialists, potential users and concerned representatives of civil society. While the first wave of JPIs tends to reflect more top-down, strategic political decisions, assisted also by the Voluntary Guidelines, the next waves of JPIs have the potential to fully exploit the different roles of FTA. Success in practice remains to be seen.

At the same time, the capacity-building role of FTA should be enabled to benefit all innovation system functions as this would lead to the accumulation of expertise and facilitate the application of FTA approaches on a contining basis. Applying FTA in the framework of joint initiatives in dealing with grand challenges should aim both to find effective solutions for grand challenges and also to enhance the strategic capabilities and the responsiveness of individuals and organisations through anticipating developmental routes and their consequences, and/or the articulating widely shared visions that steer evolutions along desirable paths. As noted earlier, this might involve challenging mind-sets which is particularly important in trying to overcome certain lock-ins and path-dependencies along specific socio-technical trajectories.

However, this role of FTA, i.e. in relation to capacity-building is the least acknowledged in joint programming activities. This would require, at the least, a dedicated preparatory phase to enable training in foresight and trust building through regular interactions among stakeholders that would allow an understanding of foresight philosophy, roles and practices. Such a preparation phase is hardly foreseen in the design of or launched new initiatives, such as the Lund Declaration[11] that shall be the basis for designing the EU's future policies for research and innovation. The ideas and frameworks set out in this

paper should inform such analyses and contribute to a better appreciation of the roles FTA can play in reorienting innovation systems towards grand challenges.

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Notes

1. Following other authors, the notional use of 'function' in this paper should not be confused with functionalist approaches found in sociology. Bergek et al. (2008) make clear that:

   > ... using the notion of an 'overall function' does not imply that all actors in a particular system exist for the purpose of serving that function or are directed by that function. Actors do not necessarily share the same goal, and even if they do, they do not have to be working together consciously towards it (although some may be). Indeed, conflicts and tensions are part and parcel of the dynamics of innovation systems.

   As Hekkert et al. (2007) point out, the notion of 'function' is useful provided its heuristic value is stressed.
2. COM(2010) 2020, Brussels, 3 March 2010.
3. COM(2010) 546 final, Brussels, 6 October 2010.
4. Article 185 of the Treaty on the Functioning of the European Union (ex Article 169 of the Treaty establishing the European Community) enables the EU to participate in research programmes undertaken jointly by several Member States, including participation in the structures created for the execution of national programmes. The ERA-NET scheme is one of the tools of the Seventh Framework Programme (FP7) to support the coordination of non-Community research programmes. It is implemented under both the Cooperation and Capacities programmes of FP7. Its objective is to develop and strengthen the coordination of public research programmes conducted at national or regional level. It provides a framework to network and mutually open national or regional research programmes, leading to concrete cooperation such as the development and implementation of joint programmes or activities. On the other hand, ERA-NET+ is a new option added to the ERA-NET scheme in FP7 allowing, in a limited number of cases, Community financial support to be provided for topping-up joint trans-national research funding.
5. Currently five JTIs exist in the fields of innovative medicines (IMI), aeronautics (Clean Sky), embedded computing systems (ARTEMIS), nanoelectronics (ENIAC) and fuel cells and hydrogen (FCH) as well as the Future Internet Initiative.
6. See <http://cordis.europa.eu/fp7/jtis/about-jti_en.html> accessed 19 Dec 2011.
7. Council of the European Union, Guidance on future priorities for European research and research-based innovation in post-2010 Lisbon strategy, Council conclusions, Brussels, 8 December 2009.
8. The Framework Conditions are concerned with the administrative, normative and regulatory factors considered essential for the effective implementation of joint programming in research and include the following: 1. Peer review procedures; 2. Foresight activities; 3. Evaluation of joint programmes; 4. Funding of cross-border research by national or regional authorities; 5. Optimum dissemination and use of research results; 6. Protection, management and sharing of intellectual property rights.
9. One example refers to the KICs. The first ones were created in the areas of climate change, energy and information and communications technologies. In 2011, the JRC-IPTS supported the European Institute of Technology to identify potential priority areas for new KICs from 2013. The proposals are based on a web 2.0 consultation of the research communities in Europe and beyond, where a number of stakeholders proposed, discussed and improved each others' ideas. The results were refined in an workshop with researchers and policy-makers representing all disciplines and from different parts of the world. Such bottom-up process was important not only for the European Institute of Technology's decision on the new KICs to be launched, but also on the design of its first Strategic Innovation Agenda.
10. See <http://www.era.gv.at/space/11442/directory/19999/doc/21643.html> accessed Dec 2011.
11. See <http://www.se2009.eu/polopoly_fs/1.8460!menu/standard/file/lund_declaration_final_version_9_july.pdf> accessed Dec 2011.

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