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Future-Oriented Technology Analysis: Its potential to address disruptive transformations

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Abstract

This paper reflects on the potential of future-oriented analysis (FTA) to address major change and to support decision-makers and other stakeholders in anticipating and dealing with transformations. It does so by critically reflecting on the selected papers for this special issue as well as on the discussions that took place at the fourth Seville International Conference on Future-oriented Technology Analysis. Considering the potential roles of FTA in enabling a better understanding of complex situations and in defining effective policy responses leads to the understanding that appropriate FTA practices are needed to enable FTA to fulfil such roles. Dealing with disruptive changes – and grand challenges in particular –, therefore, raises several conceptual, methodological and operational issues. Two of them are general, while further two are specific to the so-called grand challenges: i) distinguish known unknowns, unknown knows and unknown unknowns, ii) combine quantitative and qualitative approaches in a relevant and feasible way, iii) understand the complex and systemic nature of grand challenges, and iv) orchestrate joint responses to grand challenges. After a brief explanation of these issues, the paper outlines the main ideas of the papers published in this special issue. These present various methodological aspects of FTA approaches as well as some advances needed in practice to assist FTA practitioners and stakeholders in comprehending transformations and in tackling the so-called grand challenges.

Keywords: FTA practices, fundamental change and transformations, grand challenges

Introduction

Drawing upon a critical reflection on the selected papers for this special issue as well as on the discussions that took place at the fourth Seville International Conference on Future-oriented Technology Analysis, this paper discusses the potential of future-oriented analysis (FTA) to address major change and to support decision-makers and other stakeholders in anticipating and dealing with transformations.

The first part of this introductory paper considers the potential roles of FTA in enabling a better understanding of complex situations and fundamental transformations, as well as in devising effective policy responses to these. Through the identification that appropriate FTA practices are needed to enable FTA to fulfil its potential roles, four conceptual, methodological and operational issues are identified and discussed.

The second part highlights the main ideas of the eight papers published in this special issue. These present some advances needed in practice to assist FTA practitioners and stakeholders in comprehending transformations and in tackling the so-called grand challenges.

In this context, when analysing the potential of future-oriented technology analysis (FTA) to assist societies, decision-makers and businesses to tackle fundamental, disruptive transformations, in general, and grand societal challenges, in particular, it is important to understand the very nature of change. These could be already occurring or likely to occur with or without conscious human actions. Both would need to be identified and understood in order to allow one to be better prepared for the future and/ or shape it in order to realise a favourable future state. Transformations can occur as a result of disruptive events (i.e. unexpected, short-term and sudden events, with immediate and on-going impacts, for which we are usually unprepared), on-going processes (i.e. difficult to detect processes since change is gradual, with slow diffusion and with medium to long-term impacts), or transformation by design (i.e. change processes that are planned, such as social or economic structural transformations). Drivers of change and sudden disruptive transformations range from profound technological changes, emergence of new business models and major economic restructuring, environmental disruptions, to shifts in social norms, values and lifestyles. Current and future economic, environmental and societal challenges, as well as their combination emerge from such transformations and call for appropriate FTA activities to support and enable large entities – such as nations and group of nations –, businesses and other organisations, as well as individuals to anticipate, adapt and respond pro-actively to change.

FTA has a potentially useful role to play in enabling a better understanding of complex situations and in defining effective policy responses, including:

- Improving the quality and robustness of anticipatory intelligence and preparedness for disruptive events through the use of systematic approaches and the development of shared insights and perceptions.
- Creating spaces for dialogue between key players from different domains, with diverging views and experiences.
- Vision-building and consensus-building for considering and inducing “guided” processes of transformation.
- Shaping and defining dialogues on transformations and policy discussions on tackling these major changes, as well as research and innovation agendas to support these dialogues and policy discussions.

Innovation is both a source of, and possible key response to, disruptive transformations, if broadly conceived in technological, social, organisational and institutional terms. The scale and direction of innovation is determined by a mix of factors, many of them national in their nature, though increasingly less so as economies and societies become more globalised. In this context, FTA can contribute not only to the steering of innovation systems, but also to their adjustment, adaptability and ability to shape responses to fundamental changes.

At the same time, FTA can contribute to building 'change' capacities that allow organisations to become capable of anticipating and addressing continuous as well as disruptive change, and thus more adaptive or setting new trends and/or developing new modes of operation. This can be achieved through regular FTA activities, assisting networking and co-operation within and across organisations, which, in turn, provides insights and capabilities to shift organisations and ultimately societies towards new directions.

Appropriate FTA practices are essential to enable FTA to fulfil such roles. These should follow certain principles to ensure quality in both processes and outputs and be supported by appropriate combinations of quantitative and qualitative methods, which are fit for purpose and context, and which enable the building of trust through inclusiveness and transparency in processes, and rigour in methods. Hence, devising an FTA project requires careful planning, and well-reasoned decisions on its main features/ elements: its geographical scope, time horizon, themes, methods, participants, budget, and other resources, target audience, communication strategy, etc. Before making these design 'technical' decisions, four issues seem to be particularly relevant when considering what FTA approaches and tools would be appropriate to address certain policy needs. The first two are general ones, while the other two are related to the so-called grand challenges:

1. Known unknowns, unknown knows and unknown unknowns
2. Combining quantitative and qualitative approaches
3. Understanding the complex and systemic nature of grand challenges
4. Joint responses to grand challenges

Below we will elaborate on each of these issues.

Known unknowns, unknown knows and unknown unknowns

The three phases above denote three levels of ignorance that FTA deals with [1], [2]. Considering that FTA is an "imaginative projection of current knowledge", FTA's practical outcomes are characterised by human behaviour under subjective opinion. The subjectivity and associated ignorance due to the choices and decisions made will increase as the FTA begins to deal with more complex and uncertain issues, such as the ones involved in grand challenges [2, p. 753]. The example of Fukushima nuclear disaster exemplifies the levels of ignorance respectively (i.e. the likelihood of an earthquake; the magnitude of the earthquake; and enormous amounts of energy released and consequent tsunami with eventual devastation). Thus, the presence of subjectivity and ignorance in all forms should be kept in mind when framing and managing an FTA activity within the fuzzy boundary between what can be known and what cannot be at the time [2, p.765]. The information, knowledge and interpretation and resultant subjective opinion of FTA participants is decisive when dealing with grand challenges [3]. Thus, it is crucial to keep in mind when designing and running an FTA activity that the selection of experts [4, 5] would strongly influence the analytical results and recommendations.

Combining quantitative and qualitative approaches

FTA is an umbrella term to denote several decision-preparatory tools – (technology) foresight, forecasting and technology assessment – and thus it is not a discipline with solid, widely accepted theoretical foundations. Rather, it is a set of various approaches to the future, which share some assumptions, but differ in others. None of these approaches is a discipline on its own, either, in a strict sense. All three components of FTA draw on the theoretical framework of several disciplines. Further, actual FTA projects exploit results of scientific research, and also use scientific methods when analysing the past and the present in order to consider future options or predict the future. Besides scientific methods, various other techniques are also used. The main objective of FTA projects is to assist decision-makers with relevant analyses, observations and new ideas to be better prepared for the future (assuming that it can be predicted) or shape the future (assuming that it is not fully predetermined by the identified/ identifiable trends). In other words, while FTA activities generate new knowledge, actually both practical and scientific knowledge, these are not scientific projects per se. FTA experts and other policy analysts, nonetheless, aim at distilling scientific results from FTA projects and publish them in journals or books.

Given the nature and diversity of FTA approaches, one can think of an FTA *toolbox, but not a uniform and proven* FTA *methodology*, to be followed by all FTA projects. All FTA projects are unique, given their context: the issues to be tackled; the main objectives; the time horizon to be considered; the desire of their sponsors/ clients; the number, experience, analytical and methodological skills and value system of their participants; the level of socio-economic development of the country(ies), region(s), sector(s) or city(ies) in which they are conducted; time and other resources available for FTA, etc. In other words, it would be a mistake to search for a fixed set of methods in the sense of "one size fits all" (or "best practice"). A "recipe book" simply does not exist: we don't know to a sufficient extent what combination of methods/ tools works best in a particular context. Yet, we can – and indeed, should – certainly seek lessons by analysing cases and by trying to develop taxonomies of strategy and policy needs; systems in which FTA is conducted; and policy governance sub-systems in which FTA is embedded (or on the contrary, with which certain FTA approaches would clash). By putting together these major building blocks, one can better devise and conduct an FTA project. This claim is based on the assumption that the closer the "fit" between (i) the perceived policy needs/ opportunities to be tackled by FTA, (ii) the chosen FTA approach and its methods and (iii) the policy governance sub-system, the higher/ more favourable impacts of FLAs can be expected (assuming an appropriate quality and methodological rigour of conducting FTA) [6].

Against this backdrop, the guest editors of this special would stress that one needs to *be careful before proposing the combination of quantitative and qualitative methods as "the" way forward*, as put by [4]. No doubt, it is worth trying to combine them when it is relevant and feasible. In more details, it is *relevant* to combine these two approaches when both add value. For example, simulation models can explore the repercussions of changes in major (external) parameters, as well as the outcome of policy options and other actions. Forecasting e.g. demographic or environmental changes are also highly relevant for certain policy needs or to enable technology observers to determine the current life cycle stage of a particular technology of interest and plan their R&D strategy accordingly [7]. Qualitative techniques, in contrast, can establish casual relations (without which models can be misleading), and identify major discontinuities in trends and/ or new ones. Participatory processes build consensus when assessing the current situation and devising recommendations; create ownership of joint visions; and thus mobilise actors to take actions in order to realise the joint visions (or at least take steps in that direction). By doing so, uncertainty can also be reduced, and that is a major benefit for decision-makers, be they directors of research institutes, deans and rectors of universities, business people, or policy-makers.

The combination of quantitative and qualitative methods is *feasible* when it is not too costly in terms of time, human resources and funds required to conduct an FTA project. Excessive use of quantitative methods is likely to severely constrain participation. Practical experience clearly show that the potential participants of an FTA exercise are simply too busy to attend training courses just for the sake of being familiar with sophisticated FTA methods. Hence, an important part of the FTA toolkit, namely foresight, would be eclipsed in case the use of advanced quantitative methods is 'declared' always necessary, and benefits of participatory processes would not be reaped.

In sum, the relevance and appropriateness of FTA methods to tackle the perceived needs should have a much higher weight when designing an FTA project than the 'elegance' of methods. Simply, it would be a gross mistake trying to establish a hierarchy of particular FTA methods/ techniques based on their 'absolute advantages' (that is, disregarding the analytical tasks and the context in which these methods are applied). Also, when evaluating an FTA project, costs and benefits of certain methods (their 'fit' to the context), on the one hand, and their actual conduct (methodological rigour, efficiency, transparency, 'fairness', representation, etc.), on the other, should be assessed separately. In other words, the 'quality' of an FTA project is a complex issue, and it cannot be reduced to the question of its level of methodological sophistication. To put it in a somewhat simplified way, it is much more important to apply relevant methods in a rigorous manner than assemble a set of highly sophisticated methods, risking that this ambition would compromise rigour, due to lack of skills, miss some major factors that cannot be identified by these techniques, and deter participation.

Further, putting an excessive emphasis on the combination of quantitative and qualitative methods – portraying it as the only 'accepted' or adequate approach – would endanger diversity and competition of approaches. Without that competition a major source of methodological innovation, a means of quality assurance, and for control of costs would be lost.

Understanding the complex and systemic nature of grand challenges

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' [8] that are difficult or even impossible to solve by single actors. Grand challenges are by nature complex and largely impervious to top-down rational planning approaches. Furthermore, any attempts to address them must span a number of long-standing organisational, epistemic and sectoral boundaries [9]. Hence, such challenges concern the whole or large parts of societies and require multidisciplinary and collective action. At the same time, they do not fit into current institutional and governance structures. In that sense dealing with grand challenges introduces new conceptual, methodological and operational challenges for FTA.

Energy, climate change, natural resources, food, water, and migration are among the most widely referred grand challenges. These are very large topics with fuzzy boundaries. This means that they cut across scientific disciplines, policy domains, and governance levels [10]. They typically involve complex and systemic relationships within and between social, technological, economic, environmental, and value systems. The challenge for FTA lies in the fact that the unstructured nature of grand challenges may not fit with the existing thematic structures of decision-making. The role of FTA in this case is to achieve articulation and orchestration of activities [3]. Policy-makers are naturally concerned with changes and surprises with disruptive impacts on their domains. Therefore, it is the task of FTA to (i) identify challenges; (ii) align actors around the challenge; (iii) discuss expected and unexpected consequences of challenges; and (iv) anticipate and address transformations in response to them.

Joint responses to grand challenges

There is a need for transitions in many realms, which require cross-cutting analysis and intervention across policy domains [11, 12]. It is even more so when one tries to tackle the so-called grand challenges. The very nature of grand challenges in most cases requires co-operation and co-ordination across (i) policy domains and (ii) governance (policy) levels. We need further theoretical analyses and practical work to establish what FTA methods would be useful and feasible to facilitate co-ordination of tools/ actions used in various policy domains, as well as co-operation among policy-makers working at regional, national and supranational level. This overall question needs to be divided into several 'sub-questions', which are highly demanding themselves. Are multi-level FTA projects – that is, those that addresses an issue that need to be tackled at the level of nations and world regions, and possibly globally, too: e.g. climate changes, energy, water, use of other natural resources, migration induced by war and other conflicts, economic hardship, demographic or environmental factors – feasible in the current policy governance structures? Do we need FTA (more precisely: foresight as part of the broader set of FTA) on innovation systems and governance structures? To what extent the current decision-makers and other major 'gate-keepers' would be open to launch and finance such exercises, and accept recommendations possibly leading to fundamental changes e.g. in terms of a radical redistribution of decision-making power?

Even if the required consensus generated and resources allocated for intervention to address grand challenges, FTA still needs to develop mechanisms for orchestrated innovation activities and policy action. Systemic action is required for a collective transformation through the co-ordinated application of scientific/technological, social and business innovation simultaneously supported by political will. Furthermore, [5] and [13] underlines the on-going need for the greater involvement of stakeholders who can introduce necessary capabilities and interest in research and innovation to respond to grand challenges.

Understanding the difficulties for FTA to dealing with the grand challenges of humanity helps, therefore, improve the FTA practice in developing its approaches, where FTA needs to demonstrate that there might be opportunities for innovation and new markets in grand challenges. For instance, [14] give "waste-based innovation" as an example of such opportunity, which appears to be suitable for aligning scientific/ technological and social innovation to achieve a structural transformation.

Papers in this special issue

The papers in this special issue of TFSC discuss various methodological aspects of FTA approaches as well as some advances needed in practice to assist us in comprehending transformations. Several papers also tackle the so-called grand challenges. The papers discussed below have been initially selected by the scientific committee of the fourth Seville International Conference on Future-oriented Technology Analysis to be considered for publication with several other papers. After a four-round process of peer review and refinement the best papers are presented in this special issue.

The paper by Haegeman et al. [4] explores aspects which ought to be considered to properly combine quantitative and qualitative approaches, whereas Gao et al. [7] proposes the development of a new forecasting approach to analysing technology life cycle of a particular technology of interest. Both Hamarat et al. [11] and Kwakkel and Pruit [12] apply an approach to forecasting that uses an ensemble of different models to explore a multiplicity of plausible futures (Exploratory Modelling and Analysis) and to assess multiple scenarios to support the design of dynamic adaptive policies. De Smedt et al. [5] investigate ways, in which futures thinking – assisted by scenarios – can be used as a tool for inspiring actions and structures that address the grand challenges and for orienting innovation systems. Shaper-Rinkel [13] analyses future-oriented governance of emerging technologies in the USA and in Germany, and stresses the need of an organisational structure that includes a variety of actors and perspectives from the outset of an endeavour in order to properly foster nanotechnology by establishing governance structures able to coordinate interactions of relevant actors. Schirrmeister and Warnke [14] contribute towards building foresight capacities for systemic and structural transformations by proposing an original methodological approach that combines four specific features: inductive approach, visual inspiration, assessment of coverage of dimensions of change, and prolonged divergence. Finally, Georghiou and Harper [3] set the scene against which change is considered and show the landscape that has formed the demand and influenced the practice of FTA to show that alignment of approaches, consideration of users' perspectives and divergence, and the need for social shaping seem critical to advance FTA practice in light of anticipating disruptive innovations and events.

In more detail, Haegeman et al. [4] depart from the methodological debate that has been a relevant element of the International Seville Conference series on Future-Oriented Technology Analysis (FTA) since its launch in 2004. They claim that current trends in FTA and the increasing policy demand for robust evidence for decision-making indicate that there may be a momentum for pushing FTA towards integrating qualitative (QL) and quantitative (QT) approaches, and thus increasing the relevance of FTA for policy, businesses and society by addressing the so-called grand challenges. They introduce a three-level taxonomy – independent use of QL and QT approaches for their combination at a later stage, use of interfaces or 'bridges' between these two approaches aiming to feed one another with different inputs, and full integration of QL and QT approaches – and show how significant progress has been made in terms of relatively simple combinations but not more sophisticated and promising ones. They advocate that accessing and combining different types of information and methods can better support policy-makers since societal challenges and complex interrelated systems require a more holistic and systemic understanding of situations. Yet, a number of barriers need to be overcome. The fundamental epistemological divide between QL and QT approaches is exacerbated by the lack of mutual trust between practitioners and users of each approach due to differences in cultures, basic training and skills, as well as lack of mutual understanding, which hinders communication and overall integration. They posit that in many cases combining QL and QT approaches does not only lead to a richer analysis of possible futures, but also to a wider view on possible directions of future developments. Based on this conviction they propose several ways to support deeper integration of QL and QT approaches: (a) gradual integration in contexts where convergence of QL and QT methods seems promising, (b) use of new disciplines entering FTA to exchange practices and increase synergies, (c) support of mutual understanding by clarifying strengths and weaknesses of QL and QT methods, (d) sharing successful cases and good practices to build trust, (e) creation of technological and methodological interfaces between QL and QT approaches, (f) setting up of multidisciplinary teams from the very beginning of an exercise, (g) developing forms of dialogue and communication between the two communities, and (h) fostering collaboration at the earliest possible stage, e.g. when experts are educated. Finally, a truly innovative research effort is required to devise methodological and conceptual frameworks, approaches and tools that intrinsically (ex-ante) integrate qualitative and quantitative thinking, as well as provide guidance for the identification of the features that may help the selection of the appropriate set of tools which fit best each context.

Gao et al. [7] proposes an approach to enable technology managers to determine the current life cycle stage of a particular technology. To improve upon the S-curve, which is currently the major forecasting approach to analyse technology life cycle (TLC), they propose a model to calculate the TLC for a technology based on multiple patent-related indicators. The right understanding where a certain technology is in its TLC is important to estimate its future development, and thus decide whether to invest in it or not. The authors claim that the first step for devising a technology strategy is to decide if the technology is worth investing in by better understanding how such technology might develop in the future. In this context, the proposed model focuses on devising and assessing patent-based TLC indicators using a Nearest Neighbour Classifier, which is widely used in pattern recognition, to measure the technology life cycle stage of the selected technology. Clearly, different types of technologies may have different developing patterns, especially for those technologies close to basic science, such as biotechnology, and future research should take this into account to test the validity of the proposed model.

As the authors also acknowledge, there is a major limitation of this method to assess a given technology. It is an often-observed fact that technologies change their course because of (unpredictable) changes in the broader socio-economic context (fluctuations in demand, changes in regulation, changing/ stronger ethical concerns, scarcity of natural resources, environmental issues, etc.), as well as due to new combinations of existing and/or emerging technologies. Technology assessment activities – part of the FTA family – can also influence technological trajectories.

Two papers from the same school – Hamarat et al. [11] and Kwakkel and Pruit [12] – address the need for novel methods and techniques to support adaptive policy-making. They analyse whether models can be used at all in decision-making under uncertainty. In this context they claim that Exploratory Modelling and Analysis (EMA) is a methodology for analysing dynamic and complex systems and supporting long-term decision-making under uncertainty through computational experiments. EMA is an iterative model-driven approach for designing dynamic adaptive policies, and it deals with uncertainties by using an ensemble of different models to explore a multiplicity of plausible futures (or scenarios). Policy options across the future world ensemble are calculated and compared in an iterated process until the suggested policy provides satisfying results. Hamarat et al. [11] explore the application of EMA combined with a number of tools in a case that focuses on a large systemic transformation or transition of an energy generation system towards a more sustainable functioning. Kwakkel and Pruit [12] present three applications of EMA, using different modelling approaches, in three different technical domains and related to three different grand challenges, grounded in a systems perspective. These modelling efforts are aimed at: i) understanding plausible dynamics for mineral and metal scarcity, ii) developing a hybrid model for airport performance calculations to underpin an adaptive strategic plan, and iii) identifying crucial factors that affect a transition towards more sustainable functioning of the electricity sector.

In light of these two interrelated papers, FTA can benefit from EMA applications as it allows the: i) simultaneous exploration of a wide variety of factors [to assess their joint implications in order to better understand the systemic and structural transformations of complex systems, ii) inclusion of a multiplicity of perspectives, worldviews, mental models or quantitative models, and iii) development of dynamic and adaptive plans and policies that are adequate across the multiplicity of plausible futures. Finally, future research avenues include elaborating on the use of EMA for designing dynamic adaptive policies and the use of EMA for scenario discovery, or on the communication of EMA results to policy makers and FTA practitioners.

De Smedt et al. [5] claim that grand challenges require policy-makers to address a variety of interrelated issues, and they need to tap into uncoordinated and dispersed bodies of knowledge. Policy- and other decision-makers should therefore devise and apply more experimental approaches to creating new solutions and include a new mode of public involvement. Thus, the paper investigates ways in which futures thinking can be used as a tool for inspiring actions. It does so by analysing seventeen scenario-based projects to identify elements of good practices and principles as to how to strengthen innovation systems through scenario analysis. In this context, scenarios are seen as a tool for inspiring and orienting innovation systems. Therefore, scenarios stimulate future-oriented thinking, create a common language and understanding between stakeholders thus supporting a systematic negotiation process, and legitimate a chosen course of action though engagement and dialogue. The underlying claim is that innovation itself needs to be oriented along more sustainable pathways enabling transformations of socio-technical systems. Hence, principles on how to orient innovation systems through future scenarios require representation and collaboration as well as the integration of different modes of futures thinking which include the possible and not only probable or desired futures.

Shaper-Rinkel [13] analyses future-oriented governance of emerging technologies. She explores the role that different types of FTA played in the development of nanotechnology governance in the USA and in Germany. In the USA, FTA was used to create visionary concepts and to promote co-operation between various actors. In Germany, FTA was mainly used to shape and define research and innovation agendas. In both countries, public policy activities to foster nanotechnology were accompanied by efforts to establish governance structures to co-ordinate interactions between actors of the innovation system. The FTA tools used to develop governance frameworks for nanotechnology in these two countries differ along time. In the USA, the approach entails mainly integrated vision-building and governance network-building coupled with avoiding centralised S&T planning. In Germany, FTA is mainly used for addressing the future of existing areas of strength, with FTA activities being governed by one ministry (BMBF), focused largely on science-industry relations, and moving from forecasting activities and expert-driven identification processes towards the inclusion of expertise from a broader range of disciplines, a wider range of stakeholders and sometimes also the knowledge of lay people. In both countries, early FTA envisioned innovative future nanotechnologies, but did not support guidance either for future innovative governance or for using nanotechnology for disruptive innovation in order to address grand societal challenges. Comparing these two countries, the main difference lies in the existence of an umbrella organisation in the USA that pools heterogeneous stakeholders and that ensures the organisational continuity to use the experience and knowledge gained in distributed FTA activities. Further, in Germany the process is less co-ordinated and does not involve heterogeneous stakeholders nor make use of the knowledge gained in various FTA. Hence, the implication for future emerging technologies is that the methodology and practice of FTA should consider the governance dimension from the beginning by acknowledging that monitoring and identifying a broad field implicitly includes the shaping of the field and its governance structure by including or excluding certain type of knowledge and expertise. This claim, which is not new, implies the need for an organisational structure that includes a variety of actors and perspectives from the outset.

Schirrmeister and Warnke [14] contribute towards building foresight capacities for systemic and structural transformations by sharing their experience on a project that explores future innovation patterns. In order to underpin the recognition of structural transformation, four specific features were applied. These contributed in a specific way to opening up new perspectives on the future of innovation and potential structural transformation of innovation processes, and enabled a look into paradigm shifts rather than tackling different variants of the established system view. These features were: i) capture of indications for extra-systemic change at a micro level instead of extrapolating seemingly dominant macro-trends, ii) mobilisation of tacit knowledge as well as support a creative spirit and an easy exchange of ideas among diverse stakeholders through what they call visual inspiration, iii) rigorous assessment of coverage of dimensions of change to take into account possibly unrecognized/hidden structural changes, and iv) extended openness for diversity or prolonged divergence. Results indicate that a wide variety of hybrid value creation models with novel configurations of innovation actors emerged. These include the emergence of more active roles for users and citizens, the need for adequate enabling platforms between innovation demand and innovation supply, the need to adopt new innovation formats in order to address societal needs, and the increasing use of collective self-production facilities. From a methodological point of view, the combination of these four features, rather than their individual use, has not been described before and turned out to be quite powerful in analysing structural transformation. The project results also underlined the need for different types of innovation policy instruments to deal with newly emerging innovation patterns rather than just different priorities.

The notion of FTA addressing research and innovation policy through priority-setting and articulation of demand has shifted to the search of breakthrough science and disruptive transformations with a strong focus on grand challenges, according to Georghiou and Harper [3]. We can further extend this broader understanding by stressing that FTA can be highly relevant beyond the domain of STI policies.

In this context, Georghiou and Harper [3] provide an account of the implications for the practice of FTA in periods of instability and discontinuity much emphasised by grand challenges, transformations and disruptive changes that claim for adaptation and alignment as coping strategies. By setting the scene against which change is considered in the domain of innovation policy and in investigator-driven research they show the landscape that has formed the demand and influenced the practice of FTA. They outline that the main exception to mainstream practice has been the emergence of horizon scanning activities. The problem so far has been the superficial treatment of topics with little guidance of what might happen in the future. This has doomed such activities to a relatively small part of the picture of FTA practice. Moreover, it happens when policy-makers need to know about new and unforeseen challenges that could disrupt their activities. In this context, while there is as yet no clear methodological answer to the identification issue there has been some institutionalised responses and new organisational models of FTA, such as embedded units or continuous scanning organisations. FTA clearly has a role in articulating recognised grand challenges and, if approached correctly, instead of seeking to manage away uncertainty, FTA can accommodate it. Hence, alignment of approaches and consideration of users' perspectives, as well as divergence and the need for social shaping seem critical to advance FTA practice and assist in considering transformations that are going to take us closer to anticipating disruptive innovations and events.

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Vitae

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