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Tailoring Foresight to field specificities☆

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ABSTRACT

The paper presents an approach at improving the impact of Foresight by systematically taking into account the characteristics of the targeted research and innovation (R&I) domains when designing a Foresight exercise. The paper addresses recent developments in Foresight theory and practice which allow for deploying a hybrid methodological framework where different approaches serve different purposes in specific phases in order to tailor Foresight to a wide range of different contexts and objectives. The paper can be characterised as empirically based theory building. The theoretical framework is elaborated by applying it in two R&I fields: (i) GM plants and (ii) Nanosciences and Nanotechnologies. Hence, this research is expected to contribute improving the strategic processes of priority setting in techno-institutional arenas both on the national and international level. In particular it is suggested that the capability of Foresight to function as a systemic innovation policy instrument for enhancing innovation and learning capability could be improved substantially by tailoring the Foresight approach to the targeted innovation arena.

1. Introduction

The paper presents an approach at improving the impact of Foresight by systematically taking into account the characteristics of the targeted research and innovation (R&I) domains when designing a Foresight exercise. It builds on a conceptual framework developed in a project of the European Network of Excellence PRIME[5] which analysed content driven Knowledge Dynamics on the one hand and the development of institutional and governance arrangements on the meso- and macro-level of research (national and post-national) on the other.

☆ The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.

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[5] PRIME = Policies for Research and Innovation in the Move towards the European Research Area, European Network of Excellence (2004–2009); see: http://www.prime-noe.org/index.php (accessed November 7, 2009).

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The first section of this paper presents the background of this new development concerning Foresight methodology and synthesises the need for a proper tailoring of Foresight.

The second section proposes an analytical view of the European research and innovation system and identifies the catalytic role of Foresight in this framework. The European system is sketched in terms of "institutional arrangements" by depicting three (interrelated) arenas for the orientation, the programming and the performance of research. Foresight is presented as a systemic policy tool appropriate for contributing to a better-geared European research and innovation system by fostering the operations of each of these arenas and the relations between them.

The third section refers to the notion of "search regimes" [1] which reflects the dynamics of knowledge production (for R&I) that are shaping the various techno-scientific fields. It presents the three key dimensions of these Knowledge Dynamics: growth rate, pattern of growth and (technical, cognitive or institutional) complementarities.

In the fourth section the central proposition of the paper is presented: The design of a Foresight exercise can be adjusted to field specificities. This will be illustrated by two case studies, first in the area of genetically modified plants and then for the domain of Nanosciences and Nanotechnologies.

2. Background and rationale

2.1. Tailoring Foresight—a revision

During the last two decades the field of Foresight has developed a lot through practical experience, academic debate and mutual learning among both academics and practitioners within project contexts such as ForLearn,[6] CostA22,[7] ForSociety[8] and intense exchange with other approaches such as futures studies, technology assessment, transition management, evidence-based policy and academic disciplines such as Innovation Studies and Science and Technology Studies [2].

A number of classifications have been developed distinguishing types of Foresight with respect to approach, context and purpose [3–5]. Based on these insights, Foresight practitioners do now deploy hybrid methodological frameworks where different approaches serve different purposes in specific phases in order to tailor Foresight to each specific purpose and context. The famous "Foresight generations" [4] are no more viewed as mutually exclusive but as complementary approaches. Explorative and normative elements are combined as well as wide collective dialogue and targeted strategic conversations among key decision makers. Hybrid methodologies such as various combinations of scenario building, roadmapping, surveys and creative methods are widely used. Key Foresight concepts such as "vision" that were previously used in a rather broad and all encompassing manner have been deconstructed and are now being deployed in a more differentiated way [6,7].

At the same time the notion of Foresight as a governance tool and policy instrument has been refined. Systems of policy functions have been proposed to enable Foresight design and evaluation to tailor approaches to policy objectives ([8], ForSociety). In order to improve Foresight impact on policy strategy building it has been proposed to complement collective Foresight processes with a strategic counselling phase where the outcomes are translated into strategic choices [9].

To sum up, it seems that Foresight has been evolving from a loose collection of approaches to a complex integrated framework with a number of levers for adaptation to specific purposes and contexts and gradually, a more systematic understanding of the key elements of this adaptation is emerging. The main context variables taken into account for Tailoring Foresight are focus, objectives and policy functions on the one hand and nature of decision making structure and their relation to the Foresight process on the other.

2.2. Why more tailoring?

In this paper we address the issue of the tailoring of Foresight with respect to themes or field, i.e. directed at a certain innovation area. The need to tailor policy instruments to the characteristics of the targeted field is well grounded in insights from research on the dynamics of innovation and knowledge generation. Innovation studies have pointed out how the dynamics of innovation systems are structured by the nature of the governing technological regimes that in turn co-evolve with socio-economic and institutional framework conditions. The co-evolution trajectories are partly determined by characteristics of National innovation systems such as regulation and cultural context [10]. At the same time sectoral and technology specific determinants (technological regimes) significantly structure companies' search processes and thereby shape the dynamics of knowledge production [11]. The sectoral systems of innovation approach which is focussing on the characteristics of knowledge production has been complemented by analysis of the properties of application domains and institutional context using the notion of socio-technical regimes ([12,13], building inter alia on [14,15]).

In all these approaches to characterising innovation regimes the knowledge base plays a crucial role. "*Central to the systems approach is the view that the key resource of a firm, or an industry is the knowledge base from which it draws its competence in refining, developing and creating and selling new products*" [16]. The characteristics of the knowledge base such as complexity, diversity and observability are used as key factors for generating innovation typologies [17,18].

[6] ForLearn project and ForLearn online guide coordinated by DG JRC-IPTS; see: http://forlearn.jrc.ec.europa.eu.
[7] COST Action A22: Advancing Foresight Methodologies funded by the European Science foundation; see: http://www.costa22.org/.
[8] ForSociety was one of the Era-nets in the FP6.

All these results point to the fact that diverse innovation areas need diverse governance tools and policy instruments and that the properties of the knowledge base is a crucial factor for such a differentiation. For some time now it has been suggested that insights from innovation systems research on the systemic nature of knowledge production should be taken into account by R&I policy to better target its instruments and approaches [16]. Recently also political science approaches have been advocating the idea that innovation in the environment of the political system needs a corresponding increase in complexity of the political system or, in other words, the building of new institutions that are able to govern these innovations effectively [19]. Such approaches see 'congruence' or 'homology' of structures as necessary in order to fulfil the function of government, i.e. executing some tasks and pursuing political objectives by influencing the environment. If such congruence of structures does not occur, a corresponding failure in the working of government and a lack of legitimacy would occur [19]. In our case of Knowledge Dynamics insufficient congruence would create tensions between research actors and their institutional environment – asking for institutional change and strategic political action.

In an early attempt to explore dependency between field dynamics and Foresight success, the FORMAKIN project highlighted how Foresight works differently in close and loose-knit configurational relations [20]. However, apart from this, there are hardly any systematic accounts of the relationship Foresight design and field specificities. Therefore we aim at "deconstructing" Foresight to identify the objectives and variables that need to be adapted to match these domains' specificities.

3. Institutional arrangements in European research and innovation system

In Europe, the conduct, the funding and the strategic orientation of research and innovation have become a multi-level and multi-actor arrangement (e.g. [21,22]). Experiences from the vertical R&I coordination between local, regional and (inter-) national levels provide insights into the challenges of managing multi-layered innovation systems [23]. In effect, this complexity differentiates research and innovation policy from other policy areas – such as social or employment policies – where the Open Method of Coordination has been applied earlier on in Europe.

3.1. Governance arenas in European research and innovation system

This section presents a concept for analysing the institutional arrangements characterising the R&I system in a given research field. It builds on a framework developed by Barré (2007) in the French Futuris project [24]. We suggest to extend this concept to the *European* level, complemented by a thematic perspective – focussing on a given field of research area.

Barré's analytical perspective builds on various theoretical concepts: R&I systems, principal-agent and agency theories, strategic and distributed intelligence for innovation policy. It proposes a functional description of National innovation systems along three interacting arenas of governance:

- the arena of strategic orientation of research, borne by the political – governmental authorities, deals with the elaborating of the vision of the future of the system, in putting in place its instruments and regulations, its broad objectives and budget; it involves Government and Parliament.
- the arena of programming in between the governmental and the research performing actors, deals with (1) translating the objectives of the former in specific scientific priorities and (2) implementing the processes of funding to allocate resources to the research performers, at institutional, research group or individual level; are concerned here research funding agencies and also core funding agencies (or institutions) to universities and PROs.
- the arena of research performance is the function of the production of research and innovation, borne by PROs, universities and firms, which employ researchers, manage infrastructures; they produce, disseminate and transfer knowledge.

Each one of these three arenas functions in the context of a specific institutional arrangement.

Whereas the Futuris work has been focussed on the national level – for analysing the French R&I system – we will mainly consider here the institutional arrangements which are governing/organising public R&I system at the European level assuming that relevant thematic research and innovation areas develop across and beyond inherited national environments. This choice does not mean that the national and regional levels are not to be taken into consideration. It is clear that the research priorities set at EU level are not disconnected from the Member States strategic choices (articulated by the European Parliament and the Council). Similarly, regions – for instance those hosting the most active science clusters – have also a word to say in European research matters. But, undoubtedly, with the dynamics of the ERA building, a European R&I system is emerging, which can be mapped in the proposed framework (see Table 1).

The arena of strategic orientation: At European level, strategic policy orientation takes place, firstly in the context of the process of elaboration of the EU research budget, mainly the framework programme, with its formal interaction mechanisms linking the European Parliament, the EU Commission and the Council (here, the Competitiveness Council). This strategic steering of research is also performed through other transnational (non EU) policy frameworks of research policy integration, namely the intergovernmental institutions, such as CERN and ESA.

The arena of programming of research: At European level, the arena of programming of research refers in the fist place to the coordination work performed by various directorates of the European Commission for translating macro-objectives (global amount allocated of resources along key orientations) set in the EU budget into thematic priorities – along

Table 1
Elements characterising the three arenas of governance for R&I in the EU context.

Strategic orientation:
EU Parliament – European Commission – Council (Competitiveness Council) institutional triangle
Board of the intergovernmental research institutions (CERN, ESA, . . .)
Variable geometry policy coordination among Member States
Programming:
FP programmes priorities elaboration process, FP management
ERA-nets, JITIs, ETP, ERC, . . .
Sectoral 'alliances' (for example SET-Plan members)
Performing:
Joint Research Center, intergovernmental research infrastructures collaboration and strategic partnerships among research institutions in the Member States

with extensive formal and informal consultation of stakeholders including scientists and research organisations. These tasks which cover the responsibilities for setting priorities and programming calls at the European level encompass also the work carried out by the new European Research Council (ERC) and by intermediary coordinating institutions like ERA Nets, European Technology Platforms (ETPs) and Joint Technology Initiatives (JTIs) which develop scientific and technological road maps. Federating EU instruments like Networks of Excellence (NoEs) and large facilities which are organising research agenda at transnational levels are also to be considered as contributing to the programming of research.

The arena of research performance: The performance of research refers to the coordination of activities of all public research institutions (research organisations and universities) and of research performing firms active in Europe.

It should be stressed that although these three arenas are conceptually neatly separated, some overlapping does exists in the sense, for example, that research agencies and large PROs may prepare the overall strategic analysis in a field and lay the ground for the policy orientation. This happens, in some occasion, in ETPs or Alliances. But, even in such cases, the distinction between orientation and programming will appear, since the decision will belong to the political arena. It can simply be considered that the actors of the programming arena have contributed to the tasks of the strategic orientation arena – but did not substitute the actors of this latter arena.

3.2. Foresight objectives in the context of the three governance arenas

We choose to focus our analysis on Foresight in connection with policy and define the Foresight exercise as a project with a clear beginning and end. Hence, we exclude from our analyses embedded Foresight or scanning activities which are performed as regular operations.

Foresight can be characterised as a systemic instrument [25] aiming at enhanced capabilities in innovation systems and their parts [26]. Foresight activities are seen as functions not only to identify promising technological pathways but also to engage relevant stakeholders and create common visions into action [25,27]. Furthermore, Foresight processes are supposed to help designing new value networks that are based on the novel combinations of technologies, organisational partnerships and institutional arrangements. Towards this end, we will crystallise the functions of Foresight exercise in order to provide support in the definition of Foresight objectives within the field configurations.

Foresight objectives have been defined by [27] as follows:

- *Foresight in support to priority-setting*. Priority-setting supports the identification of common future actions and the efficient allocation of resources [28]. Priority setting may, however, decrease the diversity of options that could challenge conventional approaches and dominant designs [29] and escape from techno-institutional lock-ins [30,31]. Here, Foresight can generate ideas on alternatives and recognise the diverse perspectives in priority setting [32,33] and support finding the most appropriate priorities.
- *Foresight in support to networking*, which enhances the connectivity of the innovation system and can improve its performance [34]. However, the excessive strengthening of existing networks (see, e.g. [35]) may create path-dependencies and locking-out alternative technological options [36]. Here, Foresight can also contribute to the creative restructuring and even the destruction of lock-in conditions by engaging different stakeholders in the proactive generation of rivalling visions for competing coalitions based on different value networks with different architectures, configurations, features and standards [37,38].
- *Foresight in support to building shared visions* of the future reduces uncertainties and helps synchronize the strategies and joint actions of different stakeholders (e.g. [39]). Efforts reaching the consensus may, however, lead to conservative and abstract results [33], to the effect that existing path-dependencies are further strengthened. Nor are general abstractions readily actionable, especially if responsibilities are not clearly identified [40]. Foresight can support the exploration of alternative futures and respective techno-institutional arrangements [27].

All three Foresight objectives have a particular significance in relation to the governance arenas. In other words, Foresights for research policy purposes, can be characterised by their positioning in the governance arenas vs. Foresight

Table 2
Foresight objectives in relation to the arenas of governance.

Arenas of governance	Foresight objective		
	Priority-setting	Networking	Building visions
Strategic orientation	Macro policy priority setting	National/EU level stakeholders networks	Overall political level vision building
Programming	Programmes scientific priority setting	Programmes stakeholders networks	Sectoral vision building, context of roadmaps
Performing	Research institutions strategic processes	Research institutions partners and stakeholders networks	Research institutions first step in strategic process

objectives matrix (Table 2). In each cell of the matrix, the Foresights do not have the same actors involved, nor the same perspectives, nor the same objectives.

This leads us to the following assumptions:

- strategic orientation, programming, and performance arenas need different types of Foresights and such is the case also for priority-setting, networking, and vision-building objectives: each cell of the matrix shapes a specific framework for Foresight,
- different thematic fields refer to different 'search regimes' characterising their mode and dynamics of knowledge production – which impact the state of play in each cell of the matrix, hence the proper Foresight design.

In the next section, we will analyse the search regimes that are shaping the development of research in the fields selected for the case studies. This will enable us to identify the Knowledge Dynamics characteristics that will impact the Foresight exercises, i.e. their tailoring – using the arenas for governance × Foresight objectives matrix.

4. Knowledge Dynamics in European research and innovation system

Policy-making in arenas of strategic orientation, programming and performing is partly driven by the content and the dynamics of research activities and by the innovation patterns and interactions of different thematic fields or sectors ("Knowledge Dynamics"). At the same time this evolution is influenced by national institutional settings and policies, and also by European traditions in R&I collaboration and related policies and infrastructures. In consequence, one can observe the evolution of different configurations entailing different forms and directions of organisation, inter-organisational research collaboration, use of research policy instruments, and degrees of international inter-linkage or even post-national institutionalisation for different knowledge areas. Recent work of Bonaccorsi [41,42,1] on 'search regimes' is supporting this claim. He suggests no longer considering the entirety of 'science' as such, expecting one general type of Knowledge Dynamics (reaching from science to innovation) and one unique set of appropriate supportive public policies. On the contrary one can assume that dynamics are differentiated depending on fields and sectors [43].

The first component of field configuration relates to Knowledge Dynamics building on Bonaccorsi's initial proposal which has distinguished three abstract properties explaining differences between science-led areas.

- *Growth*. The rate of growth differs widely between fields. According to the 'World of Science' the average yearly growth of publications is around 1%, while e.g. genomics has been growing for the last 10 years at 8%, and the recent rate of growth of nanoscience has been near to 14%.
- *Convergence/divergence*. In fields that are established (with a dominant design or in 'normal science' under a given paradigm), knowledge tends to be cumulative, meaning that two different pieces produced in different places will converge towards deepening the given paradigm. But when a new paradigm is emerging, actors enter in a wide exploration, multiplying directions, and this divergence, as shown by recent biotechnology, can remain for a long period, driving to very different conditions under which new knowledge is circulated and generalised. The relative degree of convergence or divergence is thus a second key property central for considering the differences in productive patterns.
- *Complementarity*. One knows the relevance of facilities and equipments ('Big Science'), the importance of inter-, or multi-disciplinarity for frontier science, one has analysed the need for inter-institutional linkages for problem-solving knowledge (collaborations between university and industry or between researchers and clinicians, . . .). All these represent cognitive, technical and institutional complementarities which all refer to the need a researcher faces to develop collaborations in order to produce results.

We suggest to further specify and adjust these three properties in the following way, in order to be able to characterise them with appropriate indicators.

In the first place the bipolar dimension of convergence/divergence should be substituted by a notion of *pattern of growth* that encompasses additional archetypes of transformations of "bodies of knowledge" – merging, death, birth, . . . These figures of change synthesise the evolution and reconfiguration of professional communities, pools of scientific publications.

For instance, the progressive sliding of the field of biocatalysis away from ‘catalysis’ within chemistry towards biotechnologies illustrates an actual reconfiguration of a current knowledge area that is combining splitting and merging trends [44].

In a second place, the three revised dimensions of search regimes characteristics have been reformulated using the three classical networks measures relating respectively to dimensions, positions and relations. Growth is analysed through the dimensions of techno-scientific networks. Divergence is interpreted as the relative position of sub-networks or clusterings. And complementarity is assessed through the analysis of intensity of relations within the network [45].

As a third new element we suggest to broaden the analytical framework (originally designed for purely scientific environments) towards the realm of technological knowledge, in order to cover the full scope of Knowledge Dynamics. Consequently, we include also the monitoring of patent applications (technometrics). Extending the application of search regimes in the realm of technology does neither create special difficulties concerning the third dimension, complementarity. For technological research as for scientific research, complementarities will refer to the need a researcher faces to develop collaborations in order to produce results. It can be for instance through the use of facilities (e.g. technological platform), or thanks to interdisciplinary or intersectoral cooperation (e.g. research contracts between academia and industry).

Moreover, the combined analysis of scientific and technological knowledge brings a more original outcome in the sense that it provides an adequate framework for analysing researchers’ coactivity, i.e. the production by the same person of patents and scientific papers. The two strings of co-activity (scientific authorship by corporate researchers and patented invention by academics) can be analysed as linkages between the scientific networks (formed by authors) and the technological network (formed by inventors) whose intensities reflect the institutional complementarity between industry and academia within a given techno-scientific area.

Table 3 summarises the network analysis-based toolbox designed for characterising search regimes dimensions – with an initial focus on the cells highlighted in grey.

5. Tailoring Foresight to Knowledge Dynamics

In this section, we explore the implications of field specificities on the Foresight activities taking place in the three governance arenas identified in Section 2.1. We will present two illustrative cases: genetically modified plants and Nanosciences and Nanotechnologies. For each domain, we will first characterise the institutional arrangement of the governance arenas and the knowledge configurations, then we will elaborate the designs of the Foresight exercises fitted to the specific Knowledge Dynamics and institutional arrangements in these two fields.

5.1. The case of genetically modified plants (GMP)

After the completion of the human genome map in 2001, the field of genomics – sometimes labelled as post-genomics – has diversified, exploring further the systemic epigenetic complexity of protein production beyond the one gene-one function paradigm that shaped the initial researches.

Plant genomics appears in two ways as a singular island in the post-genomics knowledge archipelago. In a first place, due to its early large-scale application, plant genomics is still largely organised according to the initial paradigm of genomics. This holds especially true for the regulatory dimension concerning especially the gene diffusion from modified organisms.[9] This cognitive tension appears in the persistent scientific controversies regarding this subject that Germany’s ban on Monsanto GM maize (MON 810) has recently illustrated one more time.[10] Secondly, plant genomics is a science-based discipline where industrial companies play a major part, which means that it is regulated by a firm IPR regime.

5.1.1. GMP: institutional arrangements

Strategic orientation: At European level, the strategic orientation of plant genomics is de facto led by industry. The European Technology Platform (ETP) “Plants for the Future” is a stakeholder forum for the plant sector, including plant genomics and biotechnology that was initiated by the European Commission in 2003. It has produced a 20-year vision and a short-, medium- and long-term Strategic Research Agenda for Europe’s plant sector setting out a consensus on the research needed to fulfil the vision. This vision has de facto been considered by policy-makers at governmental and European level as the reference document for the orientation of research in this area.

Two other key elements are contributing to the future of this research field. (1) EU institutions have had a prominent legal role by delaying the introduction of GM crop in Europe. The European Union had approved a number of GM crops until late 1998, but growing public concern over their supposed environmental and health risks led several EU countries to demand the moratorium. By late 1999 there were enough such countries to block any new approvals of GM produce. Under pressure from the biotech firms, and from America and other big growers of GM crops, the EU then persuaded the anti-GM countries to replace the moratorium with a scheme in which all products containing GM ingredients would have to be labelled as such,

[9] “Les OGM face aux nouveaux paradigmes de la biologie”, meeting organised on February 11th and 12th 2009 in the framework of the ANR-OGM COBINA research project.

[10] Decision announced by Ilse Aigner, federal ministry for agriculture, on April 14th 2009.

Table 3
Search regimes analysis through scientific publications and patents' network properties assessed at journal, doc, word, person or institution levels.

	Growth–network dimension	Growth pattern–relative position of clusters within the network	Complementarities - relations within the network		
			Cognitive	Technical	Institutional
Journals network	Number of journals	Citations flows between journals	Flow of citations between clusters compared with flow of citations within cluster		
Documents network	Number of docs	Citations flows between docs clusters	Flow of citations between clusters compared with flow of citations within cluster	Platform cited within scientific publications	
Words network	Number of words				
Persons network	Number of persons				Academic patenting Industrial publications Co-active researchers' collaborations Authors cited within patents

and those ingredients traceable to their source. In 2004, the European Commission has lifted a 5-year moratorium on genetically modified produce. Since then, six countries – Austria, France, Germany, Greece, Hungary and Luxembourg – have chosen to ban Monsanto MON 810 modified maize contradicting EU Commission position. (2) NGO and green movements have strongly impeded the development of markets for any products including GM component within Europe. The decrease of "open air" researches in EU is striking when compared with the steady growth of the market for the products resulting from these explorations, for which the cultivated area of GM crops worldwide can be considered as a proxy.[11]

Programming: Concerning, academic research, the ERA-NET Plant Genomics aims at strengthening the European Research Area in Plant Genomics. It is composed as a network of research funding organisations responsible for the development of national or regional plant genomics research programmes. With a budget of over 35 M€ it is one of largest coordinated transnational research programmes in the ERA-NET scheme.

Performing: GM plant research in Europe is performed within public and private labs. Two types of collaboration can de developed at EU level: (1) private collaborative research projects funded by industry and performed by academia. This first important stream is one main engine for the institutional complementarity discussed below. (2) International cooperation through EU FP projects. This stream remains limited. A total of 46 plant genomics projects has been funded within the whole FP6.

5.1.2. GMP: Knowledge Dynamics

Growth: The research field of GM plant is characterised by a strong growth of the number of articles. This feature is clear when the evolution of volume of scientific output (+200% over 10 years, from 1996 to 2006) is compared with the changes occurring in "all science" (+50% over the same period), "agricultural and biological sciences" (+30%), "all plants" (+80%) publications.[12]

Pattern of growth: Plant genomics is a well-defined cluster in the post human genome project scientific landscape. It stands at the side of areas as human genomics, metabolics, proteomics, philogenomics, bioinformatics, genomics, cancer, . . . Like all these genomic research areas, plant genomics draws heavily on bioinformatics and is linked with environmental research.

The cognitive proliferation that keeps blooming in the field of genomics is challenging some early applications of plant genomics research jeopardising thus their industrial applications. In a nutshell, this cognitive tension stems from a shift in perspective from a rather reductionist view where the genome was considered as the blue print for life – representation that has shielded the endeavour of sequencing the human genome – towards a more holistic and systemic view where a structured genome interacts with its epigenetic surrounding.

Complementarities: (1) Cognitive: the issues of monitoring GM plants released in the environment and of co-existence between GM and non-GM plants have fostered collaboration with environmental sciences. (2) Technical: shared platforms are not central for plant genomics. (3) Institutional: plant genomics development is a science-based activity led by industrial companies. This domain displays a strong institutional (i.e. inter sectoral) complementarity between industry and academia. "Plants for the Future", the above-mentioned European Technology Platform is an example of coordinating institution for this collaboration.

[11] *Source*: ISAAA <http://gmoinfo.jrc.it/gmp_browse.aspx>.
[12] *Source*: Scopus and SJR.

5.1.3. GMP: towards a Tailored Foresight

In the field of GM plants research we find a strong growth rate and strong industrial push on the one hand and sceptical citizens and consumers and strict regulation on the other. Steering is done in an integrated manner through the Technology Platform with industry as the dominant driving force. The programming is carried out in a co-ordination mode via the ERA-NET scheme. At the same time there are indications for a low diversity in directions of plant genomic research. The immediate conclusion for Foresight is the need for consensus building among stakeholders from industry and civil society for a further development of the European research and innovation system. There seems to be a strong demand for all three Foresight objectives namely participatory visioning and priority setting as well as networking. The activities of the Plants for the Future Technology Platform have been taking exactly this direction. Its Strategic Research Agenda is based on a set of challenges and goals that was developed with a broad range of stakeholders including consumer and environmental organisations (Plants for the Future 2005). On a closer look the needs for Foresight can be specified on the base of the field analysis. It seems unlikely that the existence of consensual visions focussing on GM research alone will be sufficient in order to break out of the current lock-in situation. The paradigm shift from the one gene one function towards a holistic approach that is one the one hand challenging the safety assessment of commercialised GM plants offers on the other hand a cognitive opportunity for modifying stakeholders alignment of interests.

To sum up Foresight may serve for channelling more elements into the GM research and innovation system thus helping to relax some of the current tensions. Two types of Foresight exercises are emerging from the analysis: firstly, exploration of multiple GM futures in the broader context of agricultural system and secondly, localisation and diversification of the GM research agenda. Outcomes from both approaches could need to be fed into the strategic orientation and programming arena by a stronger institutional steering on EU level.

5.2. The case of Nanosciences and Nanotechnologies (N&N)

Nanosciences and Nanotechnologies (N&N) are seen as the ‘top-down’ miniaturisation movement of three domains: microelectronics, materials and biotechnologies and as their ‘bottom-up’ convergence at the nanoscale. To address field specificities for Nanosciences and Nanotechnologies, we will examine first institutional arrangements and later on Knowledge Dynamics.

5.2.1. N&N: institutional arrangements

Strategic orientation: European Commission has developed an active policy in the field of N&N policy. It displays explicitly among the EU policies one dedicated to Nanosciences and Nanotechnologies. The European Technology Platform for Nanoelectronics European Nanoelectronics Initiative Advisory Council (ENIAC) was launched in 2004 with the mission to bring together all leading players in the field and to develop and implement a European vision validated by policy makers and governments. It has produced a Strategic Research Agenda (SRA) created through the concerted efforts of experts from industry, academia, and public authorities across Europe.

Programming: One DG RTD service is specifically in charge of translating nano policy objectives into research programmes, ‘‘Nano- and converging Sciences and Technologies’’. A set of EU instruments have been taken up for fostering European coordination, across national and sectoral borders. The ERA-Net ‘‘NanoSci-ERA’’ is coordinating national programmes: is a Consortium of 17 national research agencies from 12 countries in the European Research Area whose objective is the coordination of the national policies in fundamental research at the nanometric scale.

ENIAC is one among the few ETP to have been further developed in a Joint Technology Initiatives (JTIs). Aimed at implementing large European research and technology development projects in Nanoelectronics, the nano JTI associates public bodies and funds (the European Commission, Member States and Associated States) and private bodies funds – through AENAS. It represents a new co-financing mechanism for collaborative transnational R&D projects expected to lever private and national investment, mobilizing around 3 billion Euros.

Performing: In fact, we face a multi-layered governance and funding system in Europe. There is a need to finance competing research projects and to provide a variety of funding sources (but mainly grant-like). A strong epistemic uncertainty exists – a premium is given to top quality universities (signalling effect). Nano excellence seems to be highly concentrated (role of ‘technology platforms’ to work at the nanoscale) in 200 clusters – where Asia has a strong presence: one third of the publications and one quarter of the clusters [46].

5.2.2. N&N: Knowledge Dynamics

Growth: The high growth rate which characterises the field (the number of scientific publication has grown from 134% between 1998 and 2006) [46].

Pattern of growth: Growth in the field of N&N is considered as a divergent dynamics, which has also been deemed as displaying proliferation traits: the field of N&N is characterised by an important intra-paradigmatic diversity. Research programmes share fundamental explanations but diverge on lower level hypotheses or experimental techniques/objects [47].

Complementarity: Research in the domain of N&N is industry driven and science based. It is characterised by a strong coactivity (publications’ authors that are as well as inventors) and an intense institutional complementarity between academia and industry. The crucial role played by shared platforms is illustrated by the limited number of N&N clusters which appear on the world map [48].

5.2.3. N&N: towards a Tailored Foresight

In the realm of nano-related research we see a strong growth rate and at the same time a strong divergence. This is not per se a problem as nano-research comprises a heterogeneous set of research activities which do not necessarily gain by integration. Nevertheless a careful analysis of potential synergies may well reveal a number of inroads for co-ordinated Foresight exercises directed at priority setting and networking within the Nano-paradigm as well as between Nano-research and other fields. An example of the latter type is the Mona roadmap[13] aiming at better integration between optics and nanotechnology. This type of Foresight is also likely to inform further integration of the programming arena and thereby strengthen co-operation at the performing level. They could be initiated, e.g. as part of the JTI or else in a bottom up manner, e.g. between a group of clusters.

Another aspect highlighted by the analysis is the need for stronger integration of citizens' perspective into the steering arena. Even though there are a number of strong technological visions around many of them lack richness on the societal side. Foresight oriented towards holistic visions building seems likely to provide relevant support here, which calls for operations in the orientation arena. The generation of socio-technical scenarios in a stakeholder dialogue may well create a more reliable ground for transferring research results into successful nano-innovations. A number of recent Foresight approaches are currently heading in this direction. Examples are the EU FP6 Nanologue project[14] where different products for different socio-technical scenarios were envisaged or the strategy articulation workshops in the framework of the Dutch Nanoned initiative (e.g. [49–51]). Besides consensual elements exercises focussing more on diversifying and opening up may be useful to avoid early lock in into dominant paradigms that may later prove less fruitful.

Finally, as for GM plants, a Nano Foresight exercise may contribute to raise research on safety assessment among the scientific priorities for avoiding the stalemate GM plants are facing.

To sum-up the analysis revealed two types of Foresight useful for underpinning the European research and innovation system in the area of Nanosciences and Nanotechnologies: (i) visioning, networking and priority setting exercises across selected sub-fields in order to explore synergies at the programming arena level; (ii) holistic visioning integrating social and technological innovation to inform the strategic orientation and programming arena and create trusted ground for nano-innovation, at the orientation arena level.

6. Conclusions

The paper set out from the notion of Foresight as a systemic innovation policy instrument supporting priority setting, networking and vision building. The paper aimed to enhance the ability of Foresight to fulfil these functions through systematically taking into account (a) the *specific characteristics of the research and innovation* area considered – its field-specific Knowledge Dynamics and (b) the institutional arrangement was described as interacting *strategic orientation, programming and performing* arenas.

The framework was illustrated by two cases: GM plants and Nano-research. Both field dynamics were described using the selected parameters. Based on this analysis conclusions for potential Foresight exercises with a relevant contribution for the development of these fields were sketched.

Even though the analysis of the two cases could only be done in a very preliminary manner it proved possible to derive meaningful conclusions for the design of Foresight exercises. For each field specific lock-in situations to be tackled by Foresight were revealed. Both cases have revealed a strong institutional complementarity reflecting an early alignment of academia and industrial research programs and much looser connections with social stakeholders. However, the pattern of proliferating growth and more precisely the paradigmatic shift away from the one-gene-one-function approach offers an opportunity for modifying stakeholders' alignment of interest for tackling persistent social concerns. Promoting research on environmental safety issues as a scientific priority for plant genomics and for nanotechnology appears as an interesting way for releasing current tensions that block this field of research – a strategic orientation that could fit in a grand challenges-based R&I policy [18].

However much remains to be done to refine the framework to function as a sound base for tailoring research and innovation policy instruments. Some relevant field characteristics were not adequately captured by the current framework. For instance, in the field of nanotechnology the need to foster the forming of new value networks around nano-products which is widely recognised remained invisible. This may be due to a lack of sensitivity towards the dynamics of the innovation and production realm compared to the academic knowledge production. Also the societal and market dynamics needs to be better integrated into the scheme. Consumer attitudes which play a key role in both case studies became relevant only indirectly in the case of GM plants as a driving factor for legislation. Finally, it needs to be ensured that tailoring of Foresight to the current dynamics of a research and innovation field does not exclude the exploration of radical changes in these dynamics.

To sum up, this paper proposes a reasonably validated framework which – beyond its acknowledged limitations – addresses directly the difficult issue of the design of Foresight activities fit for the emerging European Research Area (ERA). ERA is, in short, the integration/coordination of research and innovation policies between the EU and Member States

[13] Mona: Merging optics and nanotechnology A European roadmap for photonics and nanotechnologies 2005–2007. Exercise aimed to provide recommendations for EU R&D efforts as input for FP7 and Strategic Research Agendas in two fields (Nanomaterials & Photonics). Mona involved 300 experts with different backgrounds from industry and academia. Cf. http://www.ist-mona.org/about/roadmap.asp.

[14] http://www.nanologue.net/.

(including in variable geometry schemes). It follows that the Foresight function, in its various objectives, will have to be designed and implemented in this totally new and complex situation.

Having illustrated the proposed framework all along this article with examples dealing with the European level, we suggest our methodology is applicable indeed for designing such ERA Foresight activities – and contribute to address the challenge we face regarding both the ERA and Foresight.

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