TAILORING FORESIGHT TO FIELD SPECIFICITIES

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Summary

The paper aims 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 sets out from a notion of Foresight as systemic innovation policy instrument directed at priority setting, networking, and vision building. The paper addresses recent developments in foresight theory and practice which allows 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.

The paper elaborates a conceptual framework developed within the ERA Dynamics project in the Network of Excellence PRIME, which analyses both the content driven knowledge dynamics and the development of institutional arrangements on the meso- and macro-level of research (national and post-national levels). In order to characterise R&I domains in a manner suitable for tailoring foresight activities, a framework with the following two dimensions has been developed:

Institutional Arrangement. The institutional arrangements of a R&I System is described through the three main arenas which are characterising its functioning: Strategic orientation, Programming and Performing. These arenas can display different modes of governance: integration, co-ordination, competition and co-existence. The states of these modes of governance that shape the three arenas are considered as a specific institutional arrangement.

Knowledge Dynamics. Dynamics characterising the “search regimes” of knowledge production within a field are analysed along three dimensions: growth, divergence, complementarities.

Foresight, as a systemic policy tool, can contribute to the emergence of a well geared R&I system by improving the functioning of each of the governance arenas and the relations between them. But in order to do so it needs to take into account the specific situation of the domain with respect to institutional arrangement and knowledge dynamics.

The tentative analysis using this framework indicates that Foresight can be tailored to the needs of a specific domain, which means identifying appropriate objectives for a Foresight exercise, locating it accurately both in the R&I domain and in the R&I system at large, and organising it according to appropriate methodological options. Two case studies show that this approach seems useful and promising.

The findings have relevant implications for R&I policy aiming to tailor measures according to field characteristics. In particular, the results provide encouraging findings to be applied in the future work on tailoring foresight. 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. The careful analysis of the dynamics of the field specificities in the domain yields important insights for the type of dialogue required to underpin future oriented learning processes. It is proposed to further refine the theoretical approach and, moreover, test it in practice in real foresight projects. Furthermore, it could be interesting to adapt the approach to apply it in connection with other instruments in the FTA realm.

Keywords: Foresight, Innovation System, Knowledge Dynamics, Research Policy

Introduction

The paper aims 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 within the ERA Dynamics project in Network of Excellence PRIME which analyses 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 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 (ERIS) and identifies the catalytic role of Foresight in this framework. In the first place this section describes the ERIS in terms of "institutional arrangements" by depicting three (interrelated) arenas where are respectively set and carried out the orientation (A1), the programming (A2) and the performance (A3) of research. These arenas are then analysed in respect to their modes of governance in Europeanisation which are, presented in a decreasing scale of intensities: integration (M1), coordination (M2), competition (M3) and co-existence (M4). The distribution of a given set of governance modes in the three arenas is considered as a specific institutional arrangement. And finally, for concluding this section Foresight is presented as a systemic policy tool appropriate for contributing to the emergence of a well-geared ERIS by fostering the operations of each of these arenas and the relations between them.

The third section is dedicated to the notion of "search regimes" which reflects the dynamics of knowledge production (for R&I) which are shaping the various techno-scientific fields. It presents the three key dimensions of these knowledge dynamics: growth, convergence and (technical, cognitive or institutional) complementarities.

The fourth section analyses in the first place on an hypothetical mode a potential fitting between the objectives to be set for a foresight exercise to be carried out a in a given area techno-scientific field and the characteristic traits of this given domain of production of knowledge – considered both as specific institutional arrangements and as particular knowledge dynamics. Then, the central idea of the paper, that a foresight exercise could adjust its design to field specificities is explored further with two case studies, first in the area of genetically modified plants and then for the domain of nanosciences and nanotechnologies. These case studies assess successively the characteristics of these domains and sketch finally a proposal for two foresight exercises where objectives and organisational features are tailored to the field specificities.

1 Background and Rationale

1.1 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, CostA22, ForSociety and intense exchange with other instruments such as futures studies, technology assessment, transition management, evidence-based policy and academic disciplines such as Innovation Studies and Science and Technology Studies.

A number of classifications have been developed distinguishing types of Foresight with respect to approach, context and purpose (Georghiou 2001[1], Havas 2006[2], Barre 2001[3]). 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" (Georghiou 2001) are no more viewed as mutually exclusive but as complementary approaches. Explorative and normative elements are combined the same way 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 (Borup et al (2006)[4], De Laat (2006)[5]).

At the same time the notion of Foresight as 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 (Da Costa et al 2008[6], ForSociety[7]). 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 (Eriksson et al 2008[8]).

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[1] Georghiou, L. 2001. Third generation foresight: Integrating the socio-economic dimension. *Paper presented at the Proceedings of International Conference on 'Technology Foresight, Science and Technology'*, Foresight Center of NISTEP, Tokyo, Japan. Available at http://www.nistep.go.jp/achiev/ftx/eng/mat077e/html/mat077oe.html (last accessed 29 September 2008)

[2] Havas, A. 2006 *Terminology and Methodology for Benchmarking Foresight Programmes*, ForSociety Transnational Foresight ERA-Net, 2006, http://www.eranet-forsociety.net/ForSociety/results/index.html?dbX_sid=7d6ead80b97f2729a3ca2afb57a9e8 (last accessed 29 September 2008)

[3] Barré, R. 2001. Synthesis of technology foresight. In Strategic policy intelligence: Current trends, the state of play and perspectives, ed. A. Tübke, K. Ducatel, J. Gavigan, and P. Moncada-Paterno-Castello. *IPTS Technical report Series*, EUR 20137 EN December, 71–88. Seville: European Commission

[4] Borup, M., Brown, N., Konrad, K., Van Lente, H. (2006). The Sociology of Expectations in Science and Technology. *Technology Analysis and Strategic Management* 18(3/4), 285-298.

[5] De Laat, B.: Scripts for the Future: Using Innovation Studies to Design Foresight Tools. In Nik Brown, Brian Rappert, Andrew Webster (eds.) *Contested Futures. A sociology of prospective techno-science* Aldershot, 2000, p. 175-208.

[6] Da Costa, Olivier, Warnke, Philine, Cagnin, Cristiano and Scapolo, Fabiana (2008) 'The impact of foresight on policy-making: insights from the FORLEARN mutual learning process', *Technology Analysis & Strategic Management*, 20:3, 369 — 387

[7] http://www.eranet-forsociety.net/ForSociety/index.html?dbX_sid=7d6ead80b97f2729a3ca2afb57a9e8 (last accessed September 2008)

[8] Eriksson, E.A.; Weber, K.M. (2008): Adaptive Foresight: Navigating the complex landscape of policy strategies. In: *Technological Forecasting and Social Change*, 75 (4), S. 462-482.

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.

In this paper we focus on Foresight as a supporting instrument of research and innovation policy. Furthermore we limit our analysis to thematic Foresight i.e. Foresight directed at a certain innovation arena rather than a geographically bounded territory. However, as field characteristics also depend on the characteristics of the innovation system we explore only cases of thematic Foresight that are addressing the European level in order to ensure consistency of the findings.

1.2 Why more tailoring?

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 (Lundvall, 1992)[9]. At the same time sectoral and technology specific determinants (technological regimes) significantly structure companies' search processes and thereby shape the dynamics of knowledge production (Malerba and Orsenigo 1996)[10]. 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 into socio-technical regimes (Geels 2004)[11].

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*" (Smith 2000, p. 98)[12]. The characteristics of the knowledge base such as complexity, diversity and observability are used as key factors for generating innovation typologies (Marsili 2001)[13].

All these results point to the fact that diverse innovation arenas need diverse governance tools and policy instruments and that the properties of the knowledge base is a crucial factor for such

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9 Lundvall, B.-Å. (ed.) (1992) *National systems of innovation: Towards a theory of innovation and interactive learning*, Pinter, London.

10 MALERBA, F.R.A.N.; ORSENIGO, L.U.I.G. (1997): Technological Regimes and Sectoral Patterns of Innovative Activities. In: *Industrial and Corporate Change*, 6 (1), S. 83-118

11 Geels, F.W. (2004): Processes and patterns in transitions and system innovations: Refining the co-evolutionary multi-level perspective, *Technological Forecasting & Social Change* 72.

12 Keith Smith (2000), Innovation as a systemic phenomenon: Rethinking the role of policy: *Enterprise & Innovation Managment Studies* Vol 1, No 1, 2000 73-102.

13 Marsili, O (2001) *The Anatomy and Evolution of Industries: Technological change and Industrial Dynamics*. Edward Elgar: Cheltenham, UK and Northampton, MA.

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 (Smith 2000) [14]. 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 (Braun 2008)[15]. 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 (Braun 2008)[16]. 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.

This paper aims at exploring the implication that such - still to be proven -results could have for Foresight considered as a specific tool of science policy. It aims at identifying the extent to which Foresight exercises could be adjusted to the particular knowledge dynamics and institutional arrangements of specific R&I domains.

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 (Brown et al 2001)[17]. However, apart from this, there are hardly any systematic accounts of the relationship Foresight design and field specificities. Therefore, after having introduced our conceptual framework for distinguishing the different institutional arrangements and knowledge dynamics which are characterising the different domains of Research and innovation, we will aim at “deconstructing” Foresight to identify the objectives and variables that need to be adapted to match these domains’ specificities.

2 Institutional Arrangements in European Research and Innovation System

This section builds on an approach developed by Rémi Barré which uses three key functions for analysing the R&I systems[18]. But whereas the focus, in this initial work was on the national level

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[14] Ibid.

[15] Braun D (ed.), Special Issue on "The political coordination of knowledge and innovation policies". *Science and Public Policy* 35(4), 2008.

[16] Ibid.

[17] Foresight as a Tool for the Management of Knowledge Flows and Innovation (FORMAKIN)

Nik Brown, Brian Rappert, Andrew Webster (SATSU), Cecilia Cabello, Luis Sanz-Menendez (CSIC Madrid), Femke Merkx, Barend van de Meulen (CTS, Twente). Main report: SATSU Working paper N21 2001. http://www.york.ac.uk/org/satsu/OnLinePapers/OnlinePapers.htm#FinalReport (last accessed September 2008)

[18] This approach has been initially developed within the framework of Futuris and presented for instance in : Lesourne J., Randet D. (2006): FUTURIS 2006 : *La recherche et l'innovation en France*, Editions : Odile Jacob.

– 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.

A focus is necessary for dealing with the complexity of the (world) system of national R&I systems - in which is embedded the European system. The choice of focusing on the European level 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. EU policies incorporate, for instance through the Council as a strong intergovernmental component. Similarly, regions – for instance those hosting the most active scientific clusters - have also a word to say in European research matters.

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. Such challenges have been attributed to the systemic nature of innovation (Smits & Kuhlmann, 2004[19]), performance of innovation systems (Lundvall, 1992[20]; Edquist, 1997[21]), and processes of regionalization (Kaiser and Prange, 2004[22]) which have resulted in complex multi-layered policies especially in Europe. In effect, this complexity differentiates 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. At present, innovation policies are challenged by the global market conditions where Member States, regions or even industrial or local clusters compete for critical resources, such as knowledge, human resources, and foreign RTD investments (Kaiser & Prange, 2004[23]).

In this paper, the institutional arrangements of the European Research and Innovation System (ERIS) will be described through three arenas relating to:

- setting strategy,
- programming and
- performing research.

This framework of analysis has been further refined in various documents produced for the French Ministry of Higher Education and Research:

Barré R. (2007), *Creating a Solid Vision of ERA – 2020*, ERA-NET ForSociety, Policy Dialogue Conference, Athens 26-27 November 2007

Barré R. (2007), *La dynamique du SFRI 2006-2007: La réforme à la croisée des chemins*, Direction Générale de la Recherche et de l'Innovation, Direction de la Stratégie

[19] Smits, R. and Kuhlmann, S. (2004) 'The rise of systemic instruments in innovation policy', *International Journal of Foresight and Innovation Policy*, Vol. 1, No. 1., pp. 4-32.

[20] Lundvall, B.-Å. (ed.) (1992) *National systems of innovation: Towards a theory of innovation and interactive learning*, Pinter, London.

[21] Edquist, C. (ed.) (1997) *Systems innovation: Technologies, institutions and organisations*, Pinter Publishers, London.

[22] Kaiser, R. and Prange, H. (2004) 'Managing diversity in a system of multi-level governance: the Open Method of Co-ordination in innovation policy', *Journal of European Public Policy*, Vol. 11, No. 2, pp. 249-266.

[23] Ibid.

These arenas are regulated by various modes / intensities of the governance for Europeanisation – which are, presented, in a decreasing scale:

- Integration
- Coordination
- Competition
- Co-existence

The combinations of these modes of governance that shape the three arenas are considered as a specific Institutional Arrangement.

2.1 Governance Arenas in European Research and Innovation System

This document studies on the European level the institutional arrangements that are in place in a given field using the conceptual framework developed by Rémi Barré in the French Futuris project[2]. This analytical perspective builds on various conceptual corpuses: R&I systems, principal-agent and agency theories, strategic and distributed intelligence for innovation policy. It is based on a distinction between three arenas - or functional spaces:

- the arena of strategic orientation of research, where visions are set concerning the future of the research system, the overarching objectives, and the level of funding for R&I policies;
- the arena of programming of research, where programmatic and thematic priorities are set and where resources are allocated; in this second arena operate intermediation institutions, which prioritize, fund, regulate and interface R&I with the political processes and the stakeholders
- the arena of research performance in which operate the institutions which perform R&D, education and innovation (universities, research organisations, firms).

Below, we examine to which elements these three arenas refer to. (see also, Table 1).

The arena of strategic orientation

At European level, strategic orientation refers in the first place to institutionalised coordination mechanisms which are implemented through budgetary tools. EU budget allocated to research, mainly the framework programme, should be considered as key element in this function.

This strategic steering of research is also performed through other transnational (non EU) policy frameworks of scientific collaboration like the one which led to ESA.

Besides these internal drivers (i.e. endogenous to the system we focus on), important external (or exogenous) factors are also contributing to the strategic steering of research.

In the first place, industry actors play an important role by selecting the areas of research in which they decide to invest. The aggregated result of firms' individual strategic choices is essential in shaping the development of research. Secondly, legal framework can be another critical factor for steering research. Regulations concerning environmental or social issues (for instance REACH) can contribute to steer research. Legislative bodies should therefore be considered as belonging to this strategic orientation arena. Finally, organisations of stakeholders (industry associations, or NGO...) which are involved in the production of long term visions and of strategic agendas - for instance within European Technology Platforms (ETP) - identify desired futures and thus influence policymakers' strategic choices. They participate also in the strategic steering of research.

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 EC DGs (RTD, INFSO, Enterprise…) for translating macro-objectives (global amount allocated of resources along key orientations) set in the EU budget for thematic priorities.

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, and Joint Technology Initiatives (JTI) which could for instance develop road mapping and foresight exercises. Federating EU instruments like Networks of Excellence (NoEs) and large facilities which are organising research agenda at transnational levels should also be considered as contributing to the programming of research.

The funding of research by industry actors plays also a role for programming the production of new knowledge.

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.

Instruments and policies located in several arenas

It should be stressed that although these three arenas can be conceptually neatly separated, instruments and polices can actually be located in several arenas. For instance, ETP can be seen as belonging to the arena of strategic orientation as locus for setting strategic research agenda. And as instruments for coordinating research endeavours an ETP belongs also to the arena of programming of research. Other example, the FP belongs to the strategic orientation through its main architecture characteristics (thematic priorities, eventually the grand challenges addressed, the global volume of funding) and belongs to the arena of programming through the organisation of calls etc.

Table 1 : Elements characterising the three arenas of governance for R&I

Strategic orientation: Nature and importance of institutions coordinating strategic choices Legal and social drivers steering research strategic choices Stakeholders forum
Programming: Nature and importance of coordinating transnational institutions (academies and learned societies, intermediary coordinating institutions like ERA Nets, ETP, JTI transnational research centres, large facilities) Transnational road mapping and Foresight Extent of private funding and market drivers
Performing Transnational research centres Shared large facilities Intensity of transnational cooperation (established / raising / weak)

2.2 Modes of Governance in European Research and Innovation System

The three arenas of governance in Europeanisation provide a relevant starting point to undertand the institutional arrangements of specific R&I fields. Furthermore, to conceptualise how the actors interact in these arenas we define four modes of R&I governance. This supports the characterisation of the institutional arrangements in view of both the level (the arenas) and the form (the modes) of governance.

Building on the cultural theory (Thompson et al., 1990)[24] of social organisation, we identify four different modes of governance in the ERIS. According to the cultural theory, social organisation can be understood in view of the extent to which an individual is bound in a unit (or social group) and in view of the degree to which an individual's life is determined by external prescriptions (rules and norms). These two dimensions can be illustrated as axes that form four approaches[25] to social organisation. From the view point of governance of the ERIS, we define four modes, respectively (Figure 1, Table 2):

- Integration of R&I efforts in the ERIS
- Co-ordination of R&I activities in the ERIS
- Competition between R&I activities within the ERIS
- Co-existence within the ERIS.

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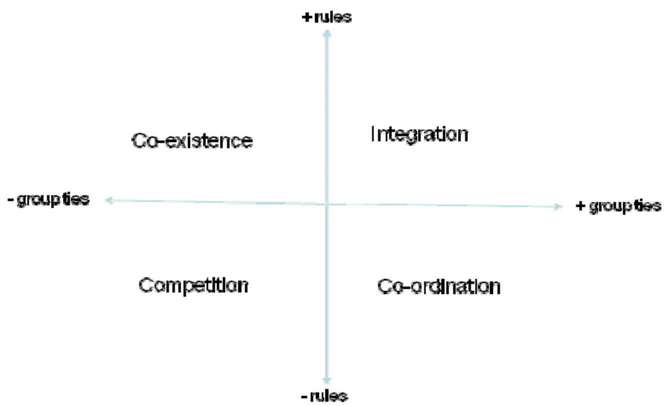
[24] Thompson, M., Ellis, R. & Wildavsky, A. (1990), *Cultural theory*, Boulder, CO, USA: Westview Press.

[25] A fifth possible way of social organisation would be the solitary person who escapes from coercive or manipulative social involvement altogether

Figure 1 : Modes of Governance



Integration

The integration mode of governance relies on the hierarchical structures and the use of power and respective means to direct the ERIS. In line with the cultural theory, the existence of strong rules and group ties refer to hierarchies, e.g. asymmetrical transactions that require accountability – hierarchical structures are used to set and execute the plans in order to direct the system. For instance, a good example of such a hierarchical top-down approach is the Kennedy´s “Man on the Moon” project, which integrated the considerable resources and efforts to reach an ambitious goal. In the ERIS, the JRC and CERN are examples of the research institutions established in the integrated manner.

Co-ordination

Co-ordination mode builds on the egalitarian perspectives in the governance. In line with the cultural theory, strong group ties and low rules, mean that different actors are equally important. Hence, instead of hierarchical relations enforcing action, the changes are achieved through the building of voluntary coalitions of actors with equal status (symmetrical transaction) and the sense of accountability (actors consider themselves accountable to one another). Thus, mutual learning and intensive communication among actors is considered as the key element in the co-ordination mode of governance. In particular, the implementation of the Dutch transition management in the national transition platforms seems to follow largely the principles of the co-ordination mode of R&I governance.

In the context of the European Research Area, already in the Fifth Framework Programme (FP5) the Commission implemented a strategic shift from the funding of technological development towards a more comprehensive innovation policy with the emphasis on the open-method of coordination (OMC), which is an inter-governmental mechanism of voluntary cooperation of

European policies (Arrowsmith et al., 2004[26]; Kaiser & Prange, 2004[27]; Schäfer, 2006[28]). In the innovation policy field, the OMC has been implemented by introducing new networks, stakeholder forums and policy processes or, more generally, coordination tools which encourage stakeholders to co-ordinate and self-organize the formation of common RD&D agendas (Könnölä et al., 2008[29]). Such coordination tools have been promoted, for example, within 'Integrated Projects', 'Networks of Excellence', 'ERA-Nets', 'European Technology Platforms' and most recently 'Technology Initiatives'.

Competition

The competition driven governance mode relies on the markets as a principle mechanism for social organisation. According to the cultural theory, low group ties and few or weak rules mean that actors are offered equal opportunities, which are exploited mainly through symmetrical transactions driven by individual interests. In line with the "invisible hand", such fragmental transactions in the markets form all together the efficient use of resources in the system. Hence, the role of governance is limited in support of the well functioning of the markets rather than directing the markets. For instance, the development of European common markets and tax reductions as R&I incentives can be seen as examples of competition mode of governance of the ERIS system.

Co-existence

Co-existence as a governance mode is fundamentally a reactive approach to develop the system. According to the cultural theory, low group ties and strong rules mean that despite the existence of rules there is no sense of accountability that would lead to proactive use of hierarchical structures. Still the rules limit the expression of individual interests which might drive to change. Thus, the passive approach may be adopted until the benefits are considered clearly higher than the costs of participation, e.d. free-riding. In the European context the limited efforts in some Member States in the participation in the development of the ERIS both in the national and the European level could be described as co-existence mode of governance. Such wait-and-see approaches may be driven partly by uncertainties in the future of the ERIS and partly by the lack of capabilities to take up more proactive modes of governance.

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[26] Arrowsmith J., Sisson K. and Marginson P., 2004, What can 'benchmarking' offer the open method of co-ordination?, *Journal of European Public Policy*, 11(2): 311–328

[27] Kaiser, R. and Prange, H. (2004) 'Managing diversity in a system of multi-level governance: the Open Method of Co-ordination in innovation policy', *Journal of European Public Policy*, Vol. 11, No. 2, pp. 249-266.

[28] Schäfer, A., 2006, A new form of governance? comparing the open method of co-ordination to multilateral surveillance by the IMF and the OECD, *Journal of European Public Policy*, 13 (1): 70-88.

[29] Könnölä, T., del Río, P., Pombo-Juárez, L., Carrillo-Hermosilla, J. and Unruh, G.C. (2008). An empirical analysis of institutional barriers to European hydrogen RD&D cooperation, *Int. J. Sustainable Development,* Vol. 11, No. 1, pp.74–96.

Table 2 : Modes of governance

Integration The proactive use of hierarchical structures with power and means to implement selected R&I activities
Co-ordination Coordination of voluntary engagement in coalitions in order to develop common R&I activities
Competition Optimising the market conditions for R&I
Co-existence Reactive wait-and-see until new opportunities

According to Thompson et al. (1990)[30], the cultural theory considers that the different forms of social organisation co-evolve in society: there is a positive feedback system that prevents extinction of any of them. In view of governance of the ERIS, it may be beneficial to develop structures that build not only one of these modes but on the positive feedback loops between the modes. Tukker and Butter (2007)[31] suggest that systemic transition processes require the interplay of different dimensions of social organisation. For instance, transitions may emerge through proactive co-ordination that may lead to changes in competition and integration modes of governance. Alternatively, the governance system may adopt a co-existence mode until the abrupt changes in the environment force governments to take up new measures in other modes of governance – for instance an economic recession leading to uptake of new policy measures to incentivise R&I as a mean to create new economic growth.

In terms of governance of ERIS, the challenge is to combine the different approaches in an effective way in the identified three arenas of strategic orientation, programming and performing.

[30] Thompson, M., Ellis, R. & Wildavsky, A. (1990), *Cultural theory*, Boulder, CO, USA: Westview Press.

[31] Tukker, A. & Butter, M. (2007) Governance of sustainable transitions: about the 4(0) ways to change the world. *Journal of Cleaner Production*, Vol. 15, pp. 94–103.

Table 3 : Characterisation of policies within the framework of arenas and modes of governance

	Integration	**Co-ordination**	**Competition**	**Co-existence**
Strategic orientation	FP7 Work Programme	OMC CREST	Common markets, National R&I strategies	Common markets, National R&I strategies / no action
Programming	ESA	Era-NETs, ETPs Art. 169, 171 (ERA-NET Plus, JTI)	National programmes with strong linkages to FP participation	National programmeswith low FP connection / no action
Performing	CERN, JRC	Partnerships, Alliances, Integrated projects	National project execution	National project execution / no action

2.3 The role of Foresight in the development of institutional arrangements

Taking into account that foresight is not a scientific discipline but rather a field a practice, there exist a multitude of alternative approaches to define both foresight functions and variables. Therefore, any attempt to typify a comprehensive and exhaustive but still a workable set of foresight definitions is bound to fail. Still, we take this challenge for the purposes of this paper, though with the following demarcation. We choose to focus our analysis on foresight in connection with the policy and define the foresight exercise as a project with a clear beginning and end. Hence, we exclude in our analyses foresight activities initiated and conducted by other stakeholders as well as activities that have ongoing nature with no clear beginning and end such as embedded activities of scanning the environment and exploring the future as part of other organisational activities.

In general, foresight can be characterised as a systemic instrument (Smits & Kuhlmann, 2004[32]) that aims at improved systemic understanding and networking and, ultimately, the enhanced innovation capabilities in the innovation system and its parts (Salo et al, 2004[33]). In view of the operational management and design of foresight projects, consideration of diverse perspectives, formation of shared knowledge and examination of alternative futures of technological and societal developments are emphasized in recent writings. Foresight activities are also increasingly seen as crucial functions to prepare for the future; not only to identify the promising

[32] Smits, R. and Kuhlmann, S. (2004) 'The rise of systemic instruments in innovation policy', *International Journal of Foresight and Innovation Policy*, Vol. 1, No. 1., pp. 4-32.

[33] Salo, A., Könnölä, T. & Hjelt, M. (2004). Responsiveness in Foresight Management: Reflections from the Finnish Food and Drink Industry. *International Journal of Foresight and Innovation Policy*. 1 (1/2): 70-88.

technological pathways, but also to engage relevant stakeholders and create common visions into action (Smits & Kuhlmann, 2004[34]; Könnölä et al., 2007a[35]). Furthermore, foresight processes can often be seen as a pertinent design phase for the creation of new value networks that are based on the novel combinations of technologies, organisational partnerships and institutional arrangements. The design and management of such processes are prone to face major challenges in responding to the diverse expectations of the client(s) and other stakeholders, and in supporting efficient R&I resource allocation, enhanced networking and operational visions for joint action. 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.

Widely discussed foresight objectives, (i.e., priority-setting, networking and common vision building) have been defined by (Könnölä et al 2007a) as follows:

- **Foresight support to priority-setting.** Priority-setting supports the identification of common future actions and the efficient allocation of resources (Irvine & Martin, 1984). Priority setting may, however, decrease the diversity of options that could challenge conventional approaches and dominant designs (e.g. Arthur, 1989) and escape from techno-institutional lock-ins (Arthur, 1994[36]; Jacobsson & Johnson, 2000[37]). Here, foresight can generate ideas on alternatives and recognize the diverse perspectives in priority setting (Salo et al., 2003[38]; Keenan, 2003[39]) and support finding the most appropriate priorities.
- **Foresight support to networking,** which enhances the connectivity of the innovation system and can improve its performance (Lundvall, 1992[40]; Martin & Johnston, 1999[41]). However, the excessive strengthening of existing networks (see, e.g. Grabher and Stark, 1997[42]) may create path-dependencies and locking-out

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[34] Smits, R. and Kuhlmann, S. (2004) 'The rise of systemic instruments in innovation policy', *International Journal of Foresight and Innovation Policy*, Vol. 1, No. 1., pp. 4-32.

[35] Könnölä, T., Brummer, V. & Salo, A. (2007a). Diversity in Foresight: Insights from the Fostering of Innovation Ideas, *Technological Forecasting and Social Change*, 74; 608-626.

[36] Arthur, W.B (1994), *Increasing Returns and Path Dependence in the Economy*. University of Michigan Press, Ann Arbor, 1994.

[37] Jacobsson, S., and Johnson, A.: The Diffusion of Renewable Energy Technology: An Analytical Framework and Key Issues for Research, *Energy Policy* 28(9), 625-640 (2000).

[38] Salo, A., Gustafsson, T., and Ramanathan, R.: Multicriteria Methods for Technology Foresight, *Journal of Forecasting* 22(2-3), 235–255 (2003).

[39] Keenan, T.: Identifying Emerging Generic Technologies at the National Level: the UK Experience, *Journal of Forecasting*, 22(2-3), 129–160 (2003).

[40] Lundvall, B.-Å., ed.: *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*, Pinter, London, 1992.

[41] Martin, B.R., and Johnston, R.: Technology Foresight for Wiring up the National Innovation System: Experiences in Britain, Austria, and New Zealand, Technological *Forecasting and Social Change* 60(1), 37–54 (1999).

[42] Grabher, G., and Stark, D.: Organizing Diversity: Evolutionary Theory, Network Analysis and Postsocialism, *Regional Studies* 31(4), 411-423 (1997).

alternative technological options (Unruh, 2000[43]). 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 (Tushman & O'Reilly, 1997[44]: Könnölä et al., 2007b[45]).

- **Foresight support to building visions** of the future reduces uncertainties and helps synchronize the strategies and joint actions of different stakeholders (e.g. Cuhls, 2003[46]). Efforts reaching the consensus may, however, lead to conservative and abstract results (Keenan, 2003[47]), to the effect that existing path-dependencies are further strengthened. Nor are general abstractions readily actionable, especially if responsibilities are not clearly identified (Salmenkaita & Salo, 2004[48]). Foresight can support the exploration of alternative futures and respective techno–institutional arrangements (Könnölä et al., 2007a).

Foresight can contribute to the development of the institutional arrangement in the different dimensions as illustrated in figure presented below.

[43] Unruh, G.C.: Understanding Carbon Lock-in, *Energy Policy* 28(12), 817–830 (2000).

[44] Tushman, M.L., and O'Reilly, C.A.: *Winning Through Innovation*, Harvard Business School Press, Boston, 1997.

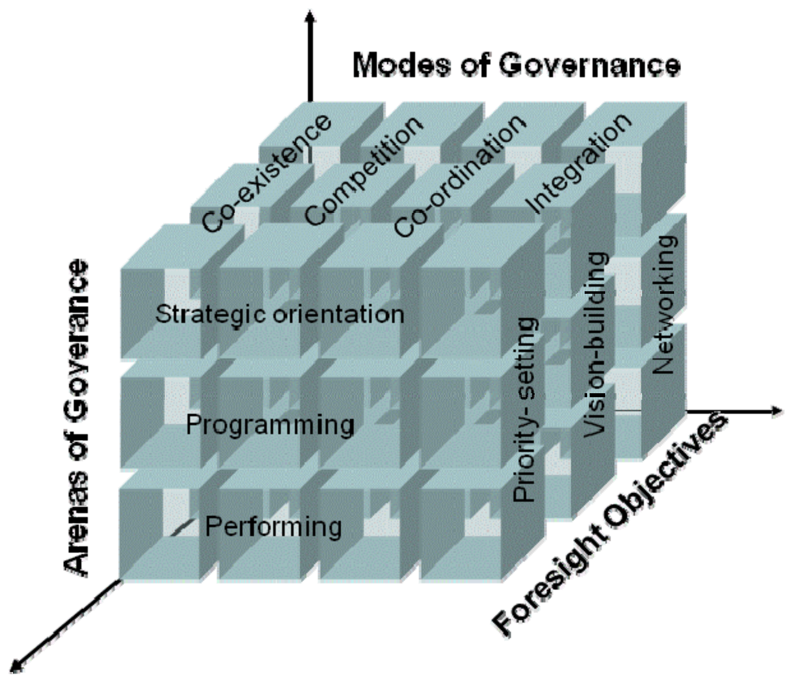
[45] Könnölä, T., Unruh, G. & Carrillo-Hermosilla, J. (2007). Toward Prospective Voluntary Agreements: Reflections from a Hydrogen Foresight project. Cleaner Production. *Journal of Cleaner Production* 15; 259-265.

[46] Cuhls, K.: From Forecasting to Foresight Processes - New Participative Foresight Activities in Germany, *Journal of Forecasting* 22(2-3), 93–111 (2003).

[47] Keenan, T.: Identifying Emerging Generic Technologies at the National Level: the UK Experience, *Journal of Forecasting*, 22(2-3), 129–160 (2003).

[48] Salmenkaita, J.-P., and Salo, A.: Emergent Foresight Processes: Industrial Activities in Wireless Communications, *Technological Forecasting and Social Change* 71(9), 897–912 (2004).

Figure 2 : Foresight objectives in relation with arenas and modes of governance.



3 Knowledge dynamics in European Research and Innovation System

This section presents the second dimension of the framework developed within PRIME for classifying field configurations.

Evolution of both national and transnational institutional arrangements and policies 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 (2005; 2007)[49] 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

[49] Bonaccorsi, Andrea (2005), *Search Regimes and the Industrial Dynamics of Science*, presentation at PRIME Annual Conference 2005, Manchester 7-8 January, 2005.

Bonaccorsi, Andrea (2007), Explaining poor performance of European science: institutions versus policies, *Science and Public Policy*, Vol. 34, Number 5, June 2007, pp. 303-316.

of appropriate supportive public policies. On the contrary one can assume that dynamics are differentiated depending on fields and sectors[50].

The first component of Field Configuration relates to Knowledge Dynamics. It builds 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. Take as a simple marker publication in the 'World of Science': while the average yearly growth is around 1%, genomics has been growing for the last 10 years at 8%, and the recent rate of growth of nanoscience has been near to 14%! One can imagine the effects of such differences by simply taking an image from management: it is well known that established positions in a market can change very rapidly when the rate of growth is 5% and higher.
- **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 toward 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. Obviously, one can afford small groups of high-level mathematicians but doubt that such a setting will be effective in biotechnology with the rise of platforms or in nanoscience with the need for clean room facilities on top of a renewed set of equipments.

Andrea Bonaccorsi has made the case for showing how useful these three dimensions can be for characterising scientific knowledge dynamics. The PRIME ERA Dynamics project has built on these results for proposing two new elements which appear in the table below.

In the first place these three dimensions 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 techno scientific sub-networks. And complementarity is assessed through the analysis of intensity of relations within the network[51].

In the second place the use of this analytical framework which has been initially designed for scientific environment has been extended towards the realm of technological knowledge in order to cover the full scope of EU level R&I policies.

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[50] Kuhlmann S. et al., 2008, *ERA Dynamics Strategic Report*

[51] Besselaar Van Den P., Schoen A., 2008, Knowledge dynamics: a network analytical approach, *Conference "knowledge for growth: European Strategies in global economy",* Toulouse – July 7-9, 2008

This extension in the direction of technology is rather direct regarding the dimensions of growth and divergence: characteristics of technological search regimes add up to those of scientific search regimes. Knowledge creators are called researchers authors in the first environment and are labelled researchers inventors in the second. Growth rate of codified knowledge is assessed either through the study of scientific publication (scientometrics) or through the monitoring of patent applications (technometrics). Width of exploration, multiplicity of research directions characterise correspondingly the relative degree of convergence or divergence of scientific or technological research fronts in both environments.

Extending the application of search regimes in the realm of technology does neither create special difficulties concerning the third dimension: 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 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 4 : Indicators and markers characterising knowledge Dynamics within a field

Growth
Scientific knowledge / size of the scientific network (nb of papers, of authors, of journals)
Technological knowledge / size of the technological network (nb of patents, nb of inventors)
Divergence
Scientific knowledge / changes of relative position of scientific sub-networks of articles clustered according to research fronts (or disciplines)
Technological knowledge / changes of relative position of technological clusters of technologies according to research fronts
Complementarity
Scientific knowledge / intensity of exchanges between researchers – nb of co-authors.
Technological knowledge / intensity of exchanges between researchers – nb of co-inventors.
Flows between academic and firms' research / Percentage of authors from firms' labs. Percentage of inventors from academic labs

4 Conclusions for Foresight

Analysing knowledge dynamics and institutional arrangements can be used as a relevant starting point for initiating field specific proactive governance practices. In this section, the governance of the ERIS is addressed from the view point of foresight activities. The role of foresight activities in the ERIS was discussed in section 2.3, which crystallised the objectives of foresight exercises as a support for priority-setting, networking and vision-building. These three general foresight objectives can be considered to be functional in term of both understanding and debating on the present state of the field specific conditions as well as on proactively developing common visions and new value networks of stakeholders to address alternative future directions and identify priorities.

Here, foresight activities should be aligned in line with the field specific knowledge dynamics and respective institutional arrangements. Hence, the foresight exercise may have very different roles to play in advancing the whole system of the ERIS. In this section, we explore the implications of field specificities to the foresight design. After discussing some general hypotheses we will develop two case studies: genetically modified plants and nanosciences and nanotechnologies. For each domain, we will first characterise the knowledge configurations, then we will examine European foresight exercises conducted in these fields and thirdly we will elaborate the designs of the foresight exercises fitted to the specific knowledge dynamics and institutional arrangements in these two fields.

4.1 Initial hypotheses on implications of field specificities on the foresight design

Our key assumption is that taking into account the field specificities can improve the quality of the design and management of foresight activities. As an example, let us consider a hypothetical case of field specificities in which knowledge dynamics consist of high diversity and growth and display only weak complementarities; and where the institutional arrangements characterising the mode of governance in Europeanisation will be mainly competitive and will be limited to the programming and performing arenas. Within such configuration, foresight projects in the strategic orientation and programming arenas might be most appropriate if they focused mainly on networking and some vision-building. Strong emphasis on priority-setting might turn out to be counter-productive, if there is lack of unanimity among the participants in the foresight project. In such cases it might be more beneficial to focus on networking and building alternative visions.

As another example, let us consider a second hypothetical case in which foresight activities should be designed within the following conditions. The knowledge dynamics would be characterised with strong complementarities, low growth and low diversity. And institutional arrangements would appear to display integrated governance modes in all three arenas of strategic orientation, programming and performance. In such configuration of “frozen” knowledge dynamics and of strongly integrated institutional arrangements, the system might require radical changes of governance. On the strategic orientation and programming levels, it could be possible to focus on vision-building for the identification of radically different future pathways and respective priority-setting to move from visions into action. However, to initiate a radical change in the system, the existing governance structures may need to be complemented or substituted with the bottom-up approaches and participation. It may become crucial to engage a wide array of participants on the performance arenas as well as other societal actors to ensure locking-out the existing pathways. The two afore sketched hypothetical cases provide some perspectives on how taking into account the field specificities may lead to different foresight objectives, participants and in general different kinds of designs of the project and used methods.

4.2 Case study on Genetically Modified plants

Research in plant genomics stem largely from the public project launched in the late 80’s which aimed at exploring the Human Genome. High throughput instruments and techniques used for investigating plants genome – for instance sequencers and DNA chips – are the same as the ones used for exploring human DNA and they have been mostly developed in this framework. Plant genomics is a science-based discipline. But the GM development of plants is largely performed by industrial companies under a strict IPR regime. Green Revolution and the Gene Revolution are different versions of global and national innovation systems in agricultural biotechnology. But they differ radically in one sense (Parayil G. 2003)[52]. Technology transfer and local adaptive work in the Green Revolution was carried out in the international public domain with the objective of developing research capacity in post-colonial Third World agriculture to increase food production to avert hunger-led political insurrection during the Cold War. Considerations of private gain and profit in the form of high returns to shareholders of agro-biotech corporations of global reach, largely, determine the dynamics of technological innovation in the Gene Revolution. To address the field specificities for GM plants, we examine first knowledge dynamics and later on institutional arrangements.

4.2.1 Knowledge Dynamics for GM plants

- **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 96 to 06) is compared with the changes occurring in "all science" (+ 50% over the same period), "agricultural and biological sciences" (+ 30%), "all plants" (+ 80%) publications[53].

- **Divergence**

Divergence of this field should be studied by characterising the cognitive structure of the scientific publications. Is it possible to identify thematic clusters of papers and patents? How do they evolve on time, do they move apart or do they converge as a single pool of plant genomics body of articles and patents? It has not been possible to perform these bibliometrics and technometrics research. As a preliminary observation, it can be stated that this field displays a limited divergence in the sense that research in plant genomics is mostly performed on a small set of vegetal species (maize, rice, soybean, oilseed rape, wheat). The first 4 plants tested in EU (out of 78 reported) represent roughly three quarters of the total number of releases[54]. Moreover these developments aim at inducing a reduced number of characteristics (mainly tolerance to insecticide and herbicide, and resistance to drought…). The crops are mainly designed to solve pest and weed problems. Latest research aims at facing climate change consequences

- **Complementarities**

Research in plant genomics stem largely from the public project launched in the late 80's which aimed at exploring the Human Genome. But the GM development of plants is largely performed

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[52] Parayil G. (2003), Mapping technological trajectories of the Green Revolution and the Gene Revolution from modernization to globalization, *Research Policy*, Volume 32, Issue 6, June 2003, Pages 971-990

[53] Source: Scopus and SJR

[54] Source: own compilation using http://biotech.jrc.it/deliberate/dbplants.asp

by industrial companies under a strict regime of intellectual property rights[55]. It can from this point of view be considered as characterised by a strong institutional complementarity.

4.2.2 Institutional arrangements for GM plants

- **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.

Two other key elements should be taken into consideration because they are contributing to the future of this research field.

In the first place, 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, and those ingredients traceable to their source. In 2004, the European Commission has lifted a five-year moratorium on genetically modified produce.

Secondly, NGO and green movements have strongly impeded the development of markets for any products including GM component within Europe. The decrease "open air" researches in EU is striking when compared with the steady growth of the market for the products resulting from these exploration, for which the cultivated area of GM crops worldwide can be considered as a proxy[56]. This evolution of number of environmental releases in Europe presented in the next table reflects this citizen/consumer resistance vis-à-vis GM plants

- **Programming**

Two instruments have been set up for coordinating at EU level the programming of research in plant genomics.

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. ERA-PG launched its first joint call for proposals in the beginning of 2006 under the title 'Structuring Plant Genomics Research in Europe'. With a budget of over 35 M€ it is one of largest coordinated transnational research programmes in the ERA-NET scheme.

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[55] Parayil G. (2003), ibid.

[56] Source : ISAAA and own computation using http://gmoinfo.jrc.it/gmp_browse.aspx

- **Performing**

GM plant research in Europe is performed within public and private labs. Two types of collaboration can de developed at EU level:

- Private collaborative research projects funded by industry and performed by academia. This first important stream is one main engine for the institutional complementarity afore mentioned. Further detailed investigations will most probably characterise a strong coactivity in these flows linking science and technology.
- International Cooperation through EU FP projects. This stream remains limited. A total of 46 plant genomics projects has been funded within the whole FP6.

Table 5 : Synthetic configuration of the knowledge production in the field of GM Plants

Growth	Strong growth rate
Divergence	Limited divergence
Complementarity	Strong inter-sectoral complementarities Limited interdisciplinary complementarities Limited shared platforms
Strategic orientation arena:	Leading role from industry – strong ETP Weak scientific steering from EU institutions Importance of legislation and citizen and consumers for the market development.
Programming arena:	Active ERA Nets and industries as driving forces
Performing arena	Limited cooperation – firms have independent research potential

4.2.3 Proposal for foresight exercise tailored to field specificities of GM plants

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 ERIS. 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.

First of all Foresight may aim to broaden the context of the GM visioning process to the agricultural system as a whole with GM research forming just one aspect. Thereby, it may be necessary to consider different possible future socio-economic framework conditions. For this purpose GM plant Foresight may take up existing Foresight results such as the agro-food system scenarios developed by a recent EU level expert group (SCAR 2007)[57]. Secondly, it may be useful to explicitly endorse alternative pathways and open up a broad debate on the values related to different futures.[58] Research topics emerging from other aspects of agricultural future visions could be taken up into the GM plants strategic orientation and programming domain. At the same time Foresight activities could serve to broaden the range of innovations targeted by GM research. In this case the focus would be rather on diversification and localisation of visions than on high level consensus building. Such an exercise could e.g. set out from the SRA challenges and translate them into concrete research projects embedded into local level governance.

To sum up Foresight may serve for channelling more elements into the GM ERIS arena 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.

4.3 Case study on 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 knowledge dynamics and later on institutional arrangements.

4.3.1 Knowledge Dynamics for Nanosciences and Nanotechnologies (N&N)

- **Growth**

The high growth rate which characterises the field (the number of scientific publication has grown from 134% between 1998 and 2006)[59].

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[57] FFRAF report: Foresighting food, rural and agri-futures (SCAR) http://ec.europa.eu/research/agriculture/scar/pdf/foresighting_food_rural_and_agri_futures.pdf

[58] C.f. the Danish Green technological Foresight where two distinctively different futures for the Danish agricultural system were developed and debated

[59] Kahane B., Delemarle A., Villard L. and Larédo P. (2008), Knowledge dynamics and agglomeration phenomena: the case of nanotechnology, *2nd PRIME Indicators Conference*

- **Convergence**

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[60]. The dynamics of science in the N&N field and the changing relation between discovery and invention

- **Complementarity**

Research in the domain of N&N is industry driven and science based. It is characterised by a strong coactivity 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[61].

4.3.2 Institutional arrangements Specificities for Nanosciences and Nanotechnologies (N&N)

- **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.

Beyond this billposting, N&N has been present among the research priorities in FP6 and FP7.

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. 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: Within Directorate G (Industrial technologies), unit G.4 takes charge of “Nano- and converging Sciences and Technologies”.

A set of EU instruments have been taken up for fostering European coordination, across national and sectoral borders.

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on STI Indicators for Policy. Addressing New Demands of Stakeholders, Oslo, 28-30th May 2008

[60] Bonaccorsi A. , 2008, The dynamics of science in the nano field and the changing relation between discovery and invention, *PRIME Winter School on Emerging nanotechnologies*, Grenoble, 4-8 February 2008

[61] Bonaccorsi A. and Thoma G. (2007), Institutional complementarity and inventive performance in nano science and technology, *Research Policy*, Volume 36, Issue 6, July 2007, Pages 813-831

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 (ERA) whose objective is the coordination of the national policies in fundamental research at the nanometric scale. It was launched on March 1 2005, under the ERA-net scheme of the 6th EU Framework Programme for Research and Technological Development (FP6).

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 and are expected to lever private and national investment, mobilizing around 3 billion Euros.

- **Performing**

It is still considered as impossible to select research directions in a centralized way. We face a multilayer governance and funding systems. There is a need to finance competing research projects 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[62].

Table 6 : Synthesis of field specificities Nano science & Nano Technology

Growth	Strong growth rate
Divergence	Strong divergence
Complementarity	Strong inter-sectoral complementarities Strong interdisciplinary complementarities Importance of shared platforms
Strategic orientation arena:	Strong steering from EU institutions and from industry. Citizen presence still limited
Programming arena:	Active ERA Net, new JTI. Industries as driving forces
Performing arena	Strong private-publics cooperation around clusters. Future inter-clusters links?

4.3.3 Proposal for foresight exercise tailored to field specificities of Nanosciences and Nanotechnologies (N&N)

[62] Kahane B., Delemarle A., Villard L. and Larédo P. (2008), ibid.

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 is comprising 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 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 on the performing level. As the field follows the integration mode of governance such exercises could be initiated through a central monitoring processe.g. in the framework of a JTI or else in a bottomup manner e.g. between 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. The generation of socio-technical scenarios in a stakeholder dialogue may well create a more reliable ground for 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[63] where different products for different socio-technical scenarios were envisaged or the strategy articulation workshops in the framework of the Dutch nanoned initiative[64]. 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.

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

5 Conclusion

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 the specific characteristics of the targeted research and innovation arena when designing a Foresight exercise. A sophisticated framework was developed in order to capture these field dynamics. The institutional arrangement was described through the mode of governance in the strategic orientation, programming and performing arenas. The knowledge dynamics was characterised by the nature of growth, convergence and complementarity. The framework was tested with two case studies: 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 the ERIS in this field were sketched.

Even though the analysis of the two case studies could only be done in a very preliminary manner it proved possible to derive meaningful conclusions for the design of EU level Foresight exercises. For each field specific lock-in situations to be tackled by Foresight were revealed. A

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

[64] http://www.nanoned.nl/TA/Research+Projects.htm

more thorough analysis e.g. of patents and publications is likely to enable even better conclusions for Foresight design. 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, the modes of governance proposed (integration, co-ordination, competition, co-existence) were addressed only partcially in the case analysis. Further efforts to address these governance modes might have led to relevant additional findings. Alternatively, the description of each R&I field on the three arenas (strategic orientation, programming and performing) might be better described individually without using too detailed a formalisation scheme. 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.

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