Innovation-system foresight: Explicating and systemizing the innovation-system foundations of foresight and exploring its implications

Andersen, Allan Dahl; Andersen, Per Dannemand

Publication date:
2012

Document Version
Publisher's PDF, also known as Version of record

Innovation-system foresight

Explicating and systemizing the innovation-system foundations of foresight and exploring its implications

Allan Dahl Andersen
DTU Management Engineering
Technology and Innovation Management
Technical University of Denmark
Email: adah@dtu.dk

Per Dannemand Andersen
DTU Management Engineering
Technology and Innovation Management
Technical University of Denmark
Email: pean@dtu.dk

1 Introduction

It has been argued that: "*foresight activities have a limited theoretical basis and respond to practical needs of exploring the future. At present a gap can be perceived between innovation theory and foresight practice, i.e. there is not specific framework available that would combine both*" (Weber, Schaper-Rinkel, & Butter, 2009). Foresight is a well-established field of practice and more recently an emerging academic field. The most academic foresight literature is descriptive or normative and relates to the practice of foresight (Miles, Harper, Georghiou, Keenan, & Popper, 2008). However, it is generally acknowledged in the literature that there is gap between practice and theory in foresight (Barré & Keenan, 2008; Hideg, 2007), and recently literature has discussed the possible 'theoretical underpinning' of foresight and possible theory building in foresight (Fuller & Loogma, 2009; Öner, 2010). This paper suggests that such underpinnings can be found in the innovation-system framework.

Taking the innovation-system framework as theoretical underpinnings and rationale of foresight can be understood as further embracing already ongoing trends within foresight. Firstly, foresight research increasingly recognizes that foresight is highly context dependent, and that context specificities must be accounted for (Barré, 2002; Cariola & Rolfo, 2004). Despite its importance, such work is currently limited (Schoen, Könnölä, Warnke, Barré, & Kuhlmann, 2011). Secondly, foresight exercises most often do not take sufficient notice of the demand for knowledge, existing competences, and the reality and wishes of firms are not adequately emphasized (Smits, Kuhlmann, & Shapira, 2010). We argue that the innovation-system framework can supply foresight with a coherent argument and methodology for including contextual factors and focusing more on demand.

Our main argument complements and contributes to several recent developments in foresight research. (1) The nexus between foresight and innovation systems have been tentatively explored by others, but they have mainly focused on how foresight can contribute to innovation-system analysis (Alkemade, Kleinschmidt, & Hekkert, 2007; Cagnin, Amanatidou, & Keenan, 2011; Martin & Johnston, 1999) while we are interested in how the innovation-system framework can contribute to foresight. (2) Others have explored practical applications of an integrated framework of innovation-system analysis and foresight (Dachs & Weber, 2010). This paper is concerned with a more foundational type of integration, not application. (3) A systems approach to foresight is not unique. Recently an explicit systems approach to foresight has emerged (Saritas, 2011). This work, though profound, is mainly about complex systems in general. It is not focused on innovation or the innovation-system framework. Our work adds an innovation focus to this work. In general though, there is according to Smits, Kuhlmann, & Shapira (2010) only litte communication between innovation-system research and foresight, and the linkages between them remain embryonic and underdeveloped. This paper can be seen as an attempt to further their integration. Its contribution is a detailed analysis of how the two areas are already intimately related, and suggestions for further integration. Our paper focuses on foresight for public policy. Our target groups are mainly foresight scholars that are concerned with innovation (not exclusively science and technology) but also as an introduction of foresight for interested innovation scholars.

The paper is conceptually explorative. It aims to make two main points. First, we will do a literature review of innovation studies and one of foresight studies. The reviews show that foresight already has theoretical foundations in innovation studies, and has coevolved with the area since its birth. Hence, theoretical underpinning already exists. Our reviews make the latter explicit which helps us to illustrate linkages and suggest how further integration can take place with respect to the research needs in foresight mentioned above. Secondly, we explore potential implications for foresight (mainly in the planning phase) of accepting the innovation-system framework as its explicit theoretical basis. We suggest implications for: (i) the goal of foresight, (ii) system definition method, (iii) degree of participation, (iv) and method for mapping of system. These considerations leave us with a range of points for further research. Both of these points constitute contributions to the literature.

The structure of the paper is as flows. Chapter 2 will present a review of innovation studies with focus on the results achieved by this field of research and on how it has changed. It concludes by presenting the innovation-system approach, and generations of innovation policy. The purpose is to define a contemporary conceptual framework for understanding innovation that can be used to link up with foresight. Chapter 3 will present, conceptualize and define the issue of foresight. It will present different generations of foresight and point out areas of current development. Given the latter we argue that there is a good argument for considering closer integration between foresight and innovation-system research. Subsequently we suggest the term 'innovation-system foresight' as a concept to aid such integration. In chapter 4, we will discuss the preliminary implications of accepting innovation-system foresight as a way forward. Chapter 5 contains concluding remarks.

2 Innovation through time: review of innovation studies

2.1 Generations of innovation dynamics

Since innovation studies emerged in the 1960s a large body of knowledge about innovation has accumulated, and researchers have gradually better understood the nature of innovation. At the same time the 'mode of innovation' has changed over time such that researchers in principle have been dealing with a 'moving target'. As a result it is possible to identify successive generations or models of innovation (Dodgson, Gann, & Salter, 2005; Rothwell, 1994)[1]. The generations reflect changes in: (i) the sources of innovation, (ii) the nature and complexity of the process, and (iii) how well we have understood (i) and (ii).

[1] The reviews referred to in the following has a clear historical focus on innovation in USA, Europe and Japan. It is thus not globally representative.

2.1.1 1st generation – the science-push model

Prior to World War 2 (WW2) science wasn't in general seen as relevant for production and economic wealth., but this changed immediately after the war due to inter alia the role of science in winning it (Lundvall & Borrás, 2005). The economic recovery in the USA and Europe was partly based on the emergence of new industries with close links to science (for example semiconductors, pharmaceuticals, and electronic computing). The public opinion was positive towards the role of science as a provider of solutions to societal problems. Given these circumstances it is hardly surprising that innovation was mainly perceived as a linear process from scientific discovery through technological development in firms, and finally to the market place. The latter is known as the linear model. The core assumption was that more R&D, the more successful new products. Besides a few exceptions the transformation of scientific output to technology and innovation was largely ignored (Rothwell, 1994).

2.1.2 2nd generation – the demand-pull model

In the mid 1960s focus was on growth, productivity and large scale industry (concentration ratios increased). New products were still being introduced, but these were mainly based on alternations of old rather than on new technological opportunities. Employment growth rates were stagnating, and due to a less expansionary environment competition between firms intensified. There was a change of focus from scale of production towards productivity and efficiency of production. The intensified competition created a stronger focus on marketing as a means to win market shares. This situation influenced the perception of innovation in a direction where demand-side factors played a more prominent role. Here the market was seen as a cradle for ideas that could orient R&D efforts which consequently was given a 'reactive role'. On this basis the 2nd generation or 'market pull' innovation model was launched (Rothwell, 1994).

2.1.3 3rd generation – the couplings model

The 1970s were a period of economic crisis where production capacity exceeded the demand for goods. Firms in general adopted a defensive strategy with focus on market consolidation and rationalization. According to Rothwell (1994) and Dodgson et al. (2005) this context stimulated a more profound interest in discovering the sources of innovation which gave rise to a number of detailed empirical studies[2]. These basically found that both the science-push and the market pull models were extreme and atypical for innovation processes. Instead the studies showed that innovation most often is a process of interaction between technological opportunities and market needs. Innovation was now seen as a process consisting of distinct but interacting and interdependent stages as e.g. continuous processes of feedback between design, product development, production, and marketing with varying links to the science and research community. Hence, focus was on interactions between phases and actors (Kline & Rosenberg, 1986; Rothwell, 1994). The model thus combines supply-push and demand-pull perspectives. One conclusion was

2 Rothwell (1994) refers to: (Cooper, 1980; Hayvaert, n.d.; Langrish, Gibbons, Evans, & Jevons, n.d.; Myers & Marquis, 1969; Rothwell et al., 1974; Rothwell, 1976; Rubenstein, Chakrabarti, O'Keefe, Sonder, & Young, 1976; Schock, 1974; Szakasitz, 1974; Utterback, 1975).

that though science is essential to innovation it is often not the initiating step. Instead, it is employed at all points along the process of innovation, as needed. Hence, the role of science can best be understood as both a leader and a follower in innovation (Nelson & Rosenberg, 1993)**.**

2.1.4 4th generation – the integrated model

The early 1980s saw a period of economic recovery where firms were increasingly and explicitly aware of the strategic importance of developing and using new (generic) technologies. In this context the rise of information and communication technologies (ICT) were central to developing new types of products and organization. Meanwhile the global outlook of firms increased and the notion of a global strategy became common as the number of both domestic and international strategic alliances grew. The rise of Japanese firms in the 1980s was central to changes in innovation studies. It became clear that they were superior in innovation, and 'western' firms started to look for inspiration in the Japanese product development system which was characterized by short product life cycles and low production costs. According to Rothwell (1994) this performance was based on their ability to in an early phase integrate firm-external and -internal actors in product development processes simultaneously. Here the stages of the innovation process are not seen as sequential but rather as *mutually integrated* (in parallel) which implies intensive communication of information and knowledge between actors. Hence, this model describes more complex information flows within the firm and with multiple sources of innovation as knowledge bases, users, producers, universities and other partners (Dodgson et al., 2005).

2.1.5 5th generation – the systems model

During the 1990s firms increasingly value knowledge and creativity, and became more skilled in innovation management. The fifth generation model is characterized by the introduction of ICT systems that are able to speed up the innovation processes. Rothwell (1994) formulated this as that the technology of technological change was itself changing because ICT has the capacity to speed up parallel and integrated processes of innovation (via faster/better communication). This further intensifies the features of the 4th generation model. The strategic environment for firms became further globalized and increasingly took the shape of a network economy where firms are mutually interdependent. Here value increasingly stems from connectedness to networks rather than ownership of capital (Dodgson et al., 2005). Innovation is thus becoming more of a networking process involving strong and early vertical linkages, use of electronics-based design and information systems, and horizontal linkages (joint R&D and strategic alliances). On this basis Rothwell defines innovation as *process* of know-how accumulation (learning process) involving elements of internal and external learning.

The 5th generation innovation model reflect fundamental changes in the dynamics of capitalist market economies reflecting the emergence of the *'learning economy'* (Lundvall & Johnson, 1994). Here knowledge is the most important factor for economic performance and learning the most important process. The main point is that not only has knowledge become more important, but what is truly novel in our time is the speed with which economically useful knowledge changes. A learning economy is an economy where the ability to learn is crucial for the economic success of individuals, firms, regions and national economies. In the learning economy increasing complexity, competitive pressures and 'limitedness' of firm knowledge imply that firms need to collaborate, because the innovation-relevant knowledge is distributed across a range of actors and knowledge bases in society (Foss & Foss, 2002). Hence, innovation is best understood as a distributed and systemic process where firm-external knowledge and learning are crucial factors. The growing importance of firm-external linkages suggests a systems approach to understanding innovation which focuses not only on the performance of individual firms, but also on how they are embedded into complex social and economic relationships in their environments - the latter points to an **innovation system** framework (Smith, 1999). The generations of models are in many ways the micro foundations for the innovation-system approach which brings together the most important results from four decades of innovation studies.

2.2 Innovation Systems

The core topic of innovation-system research is to understand the interaction between technological change and economic performance, which often takes place via international competitiveness. The approach emphasizes the *interdependence between technical and institutional change* as the central theoretical area (Freeman, 2003)[3]. The focus on institutions is important because it draws attention to patterns of interaction and to how they differ across contexts.

Text box 1 illustrates a range of diverse but complementary definitions of an innovation system. It is obvious from these definitions that especially institutions, organisations and their interactions are the main factors that determine the IS[4]. This paper will rely on the broad and basic definition given by Lundvall who defines an innovation system as "the elements and relationships which interact in the production, diffusion and use of new, and economically useful knowledge" (Lundvall, 1992). It is further stressed that such a system is a social and a dynamic system. Within an innovation system the most centrally placed type of organization is most often the firm because firms are responsible for production and for improving production via introduction of new knowledge.

2.2.1 Different levels and boundaries

When the innovation-system approach emerged it was in the form of a National Innovation System (NIS) concerned with how nations can build knowledge infrastructure for economic development (Lundvall, 1992; Nelson & Rosenberg, 1993). Since, the framework has developed in different directions because not all found the national level appropriate.

---

3 Institutions are defined as sets of common habits, routines, established practices, rules, or laws that regulate the relations and interactions between individuals and groups (Edquist & Johnson, 1997). A main point is that institutions provide an incentive structure for human behavior, which in turn will determine the attainable economic outcome in a given context (Sokoloff & Engerman, 2003). This structuring view of institutions underlies the often-used phrase that institutions are the rules of the game. They facilitate the regulation of social behavior which supplies stability to societies – a stability that is mandatory for its reproduction. Institutions mainly affect innovation via their effect on interactive learning. This refers to how institutions influence the way communication, interaction and knowledge sharing take place in society

4 Organisations and institutions are seen as distinct although they interact and affect one another. Organisations are actors such as firms, universities and states. Institutions on the other hand influence how actors behave.

The latter diversity covers different levels and dimensions as the regional IS (RIS) (Asheim & Gertler, 2005; Cooke, Uranga, & Etxebarria, 1997), the sectoral IS (SSI) (Malerba, 2002, 2005) and the technological IS (TIS) (Bergek, Hekkert, & Jacobsson, 2008; Carlsson & Stankiewitz, 1995).

The different approaches reflect that an IS may be delimited (i) spatially, (ii) sectorally or (iii) according to technology/knowledge base. These determinants of limits may be applied in a mix and may all be fruitful given the object of the research because they complement rather than exclude each other. The flexibility in defining innovation system level and boundaries comes from seeing the economy as an evolving complex, *open* system – a recursive system (Arthur, Durlauf, & Lane, 1997). The latter implies that innovation systems interact and are mutually interdependent, and that every system is embedded in a broader social system, see figure 1.

"... The network of institutions in the public- and private-sectors whose **activities and interactions** initiate, import, modify and diffuse new technologies" (Freeman, 1987).

"... The set of institutions whose **interactions** determine the innovative performance of national firms" (Nelson & Rosenberg, 1993).

"... The national system of innovation is constituted by the institutions and economic structures affecting the rate and direction of technological change in the society" (Edquist & Lundvall, 1993).

"... A national system of innovation is the system of interacting private and public firms (either large or small), universities, and government agencies aiming at the production of science and technology within national borders. Interaction among these units may be technical, commercial, legal, social, and financial, in as much as the goal of the interaction is the development, protection, financing or regulation of new science and technology" (Niosi, Saviotti, Bellon, & Crow, 1993).

"... The national institutions, their incentive structures and their competencies, that determine the rate and direction of technological learning (or the volume and composition of change generating activities) in a country" (Patel & Pavitt, 1994).

"... That set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provides the framework within which governments form and implement policies to influence the innovation process. As such it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artifacts which define new technologies" (Metcalfe, 1995).

Text Box 1: Definitions of an innovation system (Lundvall, Joseph, Chaminade, & Vang, 2009)**.**

The different approaches reflect the diversity of innovation dynamics that we can observe in the real world. Innovation dynamics differ across contexts because: (i) industries depend on different knowledge bases, and the technological opportunities differ across knowledge bases as a consequence of existing strongholds in production, science and technology; (ii) technological and innovation competences, embodied in people and firms, are unequally distributed across space and time as a consequence of specialization of industrial structure and of education system; (iii) the quality and volume of demand for output differs across industries which results in diverse demand-pull effects (Dosi, 1988). Moreover, institutions relating to patents, appropriability conditions, competition and market structure differ in importance across industries (Nelson & Rosenberg, 1993; Pavitt, 1984). These insights generate an argument saying that innovation is a context-dependent phenomenon, and that therefore should avoid 'unnecessary' aggregations and generalizations.

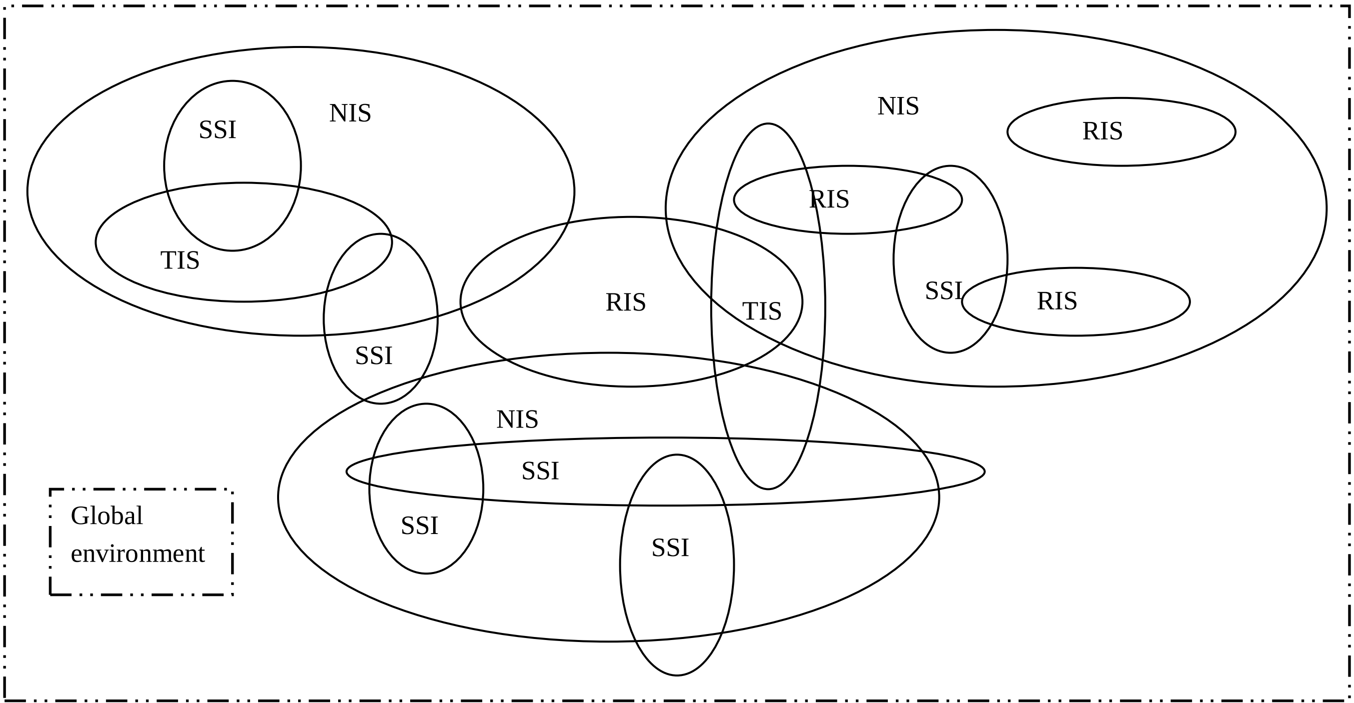

Figure 1: System overlap, interaction and interdependency (A. D. Andersen, 2011).

2.2.2 A theoretical core

Despite diversity within the approach a basic theoretical core can be identified. The central building block is evolutionary economics (Johnson, Edquist, & Lundvall, 2003). The main ontological consequences are: (i) absence of equilibrium assumptions. An economic system never fully reaches equilibrium; it is always characterized by disequilibria, change and 'structural tensions' – dynamics first (Dahmén, 1989; Nelson, 1995); (ii) social systems evolve over time in a path-dependent manner which is characterized by positive and negative feedback mechanisms (Arthur, 1994); (iii) The individual is understood as subject to 'bounded rationality' and limited information-processing capacity, which makes choices and search local rather than global (Simon, 1983); (iv) consequently innovation follows certain, and different, trajectories across time and space (Dosi, 1982). Hence, one should expect diversity in systems across time and space, and not identical systems. Other characteristics shared by the IS approaches that are not directly derived from, but compatible with an evolutionary stance are: (v) that knowledge is different from information, and that parts of knowledge are tacit and others are localized (result of path-dependent learning) (Winter, 1987); (vi) knowledge and information are shared and flow in relationships between actors; (vii) knowledge is a result of learning, and learning is predominantly interactive (Nooteboom, 2000); (viii) knowledge and learning are inputs to innovation, which is a fundamental factor in economic development (Boulding, 1981).

A pivotal proposition in the innovation-system framework is that the most central activity in an innovation system is learning and that learning is mainly interactive (Johnson, 1992). Nooteboom (2000) argues that as competition, specialization, and in turn complexity increase, the value of firm-external knowledge increases, which makes interactive learning the most important type of learning. The explicit introduction of interactive learning to innovation studies came in the form of user-producer interaction (Lundvall, 1985). Lundvall argues that innovation emerges from a confrontation of user needs with technological opportunities. Users naturally know more about their own needs than producers, and producers know more about technological opportunities than users. This situation entails interdependence in innovation endeavors between users and producers via exchange of information and interactive learning. This inter alia implies that (i) communication skills and ability to identify problems and possibilities on behalf of both users and producers become very important; (ii) avoiding system lock-in situations is as important as creating new ones systems; (iii) the competence of users (of knowledge) is as important as the competence of producers (of knowledge). Despite being crucial for interactive learning the latter is often neglected (Laestadius, 1998, 2000) On a more aggregated level the quantity and quality of interactions between organizations in an economy are likely to improve the 'efficiency' of innovation activities and performance of the innovation system (Fagerberg, Mowery, & Verspagen, 2009; Lundvall, 1985).

As we have seen the innovation-system framework systematically links the features of the 5th generation model, and partly on that basis builds a tentative theoretical framework that can be used to explain and understand the relations between science, technology, innovation and economic performance. There is significant diversity within this innovation-system tradition but it is beyond the scope of this paper to explore.

2.3 Generations of innovation policy

As the understanding of innovation processes have improved and as the mode of innovation itself has changed, the rationale for policy intervention to stimulate innovation activity has also changed. Lundvall and Borrás (2005) identify three ideal types of innovation policy in the post WW2 period: (a) science policy, (b) technology policy, and (c) innovation policy[5]. (a) The type of innovation policy pursued immediately after WW2 is characterized as **science policy** which basically relies on the first generation linear model of innovation. Science is seen as capable of solving the problems of society. With this perspective the most important activity is basic science and the most relevant

5 These ideal types are difficult to precisely pinpoint in time but they are rooted in different policy rationales that are related to the changing understanding of innovation.

actors are universities and research institutions. (b) During the 1960s the rationale behind science policy evolved into **technology policy** which emphasizes the links to industry. The objective changed from being about more science, to addressing economic objectives. Attention moves beyond basic science towards engineering, and from the internal organization of universities toward how they link to industry. The change of emphasis reflects an increasing role for the demand side in the innovation process (elements of the 2nd and 3rd generation models), and thus includes several other elements as firms, industrial policy, technology transfer and private R&D institutes. The shift clearly reflects a critique of the linear model. (c) The **innovation policy** ideal type is derived from the insight that innovation is a systemic process. Here innovation policy basically concerns all relevant aspects of society that influences the process of innovation which makes policy **systemic**. Besides the importance of science and technology transfers to industry, the innovation system approach is concerned with the building of firm-internal capabilities and the increasing number of firm-external couplings relevant for innovation. Hence, innovation policy is concerned with the couplings and interactions between the parts of the system[6].

The systemic and distributed character of innovation has implications for participation in policy-making processes. It has been recognized that effectiveness (implementation) of policy to a large extent depends on the involvement of a broad range of actors besides those formally in charge. Due to the complexity of the learning economy, policy formulation relies on the knowledge, experience and competence of stakeholders. Since policy-makers cannot be understood as perfectly informed social planners distributed policy-making via inclusion of key stakeholders is the only sensible alternative. Moreover, often it is these stakeholders who must alter behavior for policies to be implemented. Hence, for policies to be effective participation of stakeholders in the process of policy development is needed (Ahlqvist, Valovirta, & Loikkanen, 2012). The latter implies that broad inclusion has a strong instrumental value for innovation policy.

2.4 Overview

The review above have illustrated that the understanding of innovation has broadened over time. Table 1 illustrates the generalized characteristics of the different generations of innovation models. These models of innovation coexist. Even though the pure science push and market pull models hardly exist then one can talk of a balance leaning towards one of these models (Dodgson et al., 2005). Table 1 also links the generations of innovation models with the different types of innovation policy. It is obvious that as the concept of innovation broadens, the parameters considered relevant for innovation policy increase in number. In this sense the 5th generation model contains all the other generations that would each constitute special cases of the 5th generation. The ideal of systemic innovation policy that emerged with the 3rd generation only gradually took hold, and was continuously developed from that point forward.

---

[6] One can say that the rationale for (a) and (b) is *market failure* while the rationale for (c) is both *market failure* *and* *system failure* which refers to failures in e.g. institutions or couplings – factors that go beyond the market (Lundvall & Borrás, 2005).

An important point stemming from the review is that innovation policy can and should incorporate science policy and technology policy in order to coordinate these interdependent dimensions of an innovation system. The division of labor between these dimensions can be broadly be described by three overlapping and continuously ongoing subprocesses: (i) production of knowledge; (ii) transformation of knowledge into artifacts; and (iii) matching of artifacts, and market needs and demands (Pavitt, 2005), see figure 2.

Generation	**1st**	**2nd**	**3rd**	**4th**	**5th**
Name	Science push	Demand pull	Coupling or chain-linked model	Integrated model	Systems model
Background	Optimism on behalf of science	The growing importance of marketing	Crisis and scarce resources – more research on innovation	Infusion of learning about innovation success in Japan	Intensified globalization of markets, finance and R&D;
Time	1950s - mid 1960s	Mid-1960s – early 1970s	Early 1970s – mid 1980s	Mid-1980s – mid 1990s	Mid 1990s – present
Key character-istics **View on the process**	The innovation process runs from science and R&D to the market. It is linear and sequential.	The innovation process runs from the market needs to science. It is linear and sequential.	Technological opportunities and market needs interact in non-deterministic ways. The process seen as sequential, but with feedback loops (non-linear)	Designed manufacturability; Integrated and parallel processes of innovation and development. Requires intensive information exchange.	Open; distributed; networking, system; internal and external learning; Innovation as process of know-how accumulation and learning
Policy ideal type	Science policy	Technology policy	Innovation policy	Innovation policy	Innovation policy

Table 1: Generations of innovation models and policy (developed by authors).

There is no a priori hierarchy between these processes. Their mutual interdependence is illustrated by the two-way arrows (interactive learning). ‘Science systems’ are an important factor, but most countries are (relatively) weak in this respect, and there is not always a clear cut relation between e.g. investments in science, R&D and in turn innovation and economic performance (Freeman 1995). Therefore focusing primarily on the science and technology system can result in misleading policy conclusions (Johnson, Edquist et al. 2003; Lundvall 2007).

Despite the diversity in innovation models and policy rationales they are not equally valuable for understanding innovation, diagnosing problems and prescribing solutions. The sources and processes of innovation have changed over time, and the innovation-system approach (and innovation policy) must be understood as analytically superior to prior models.

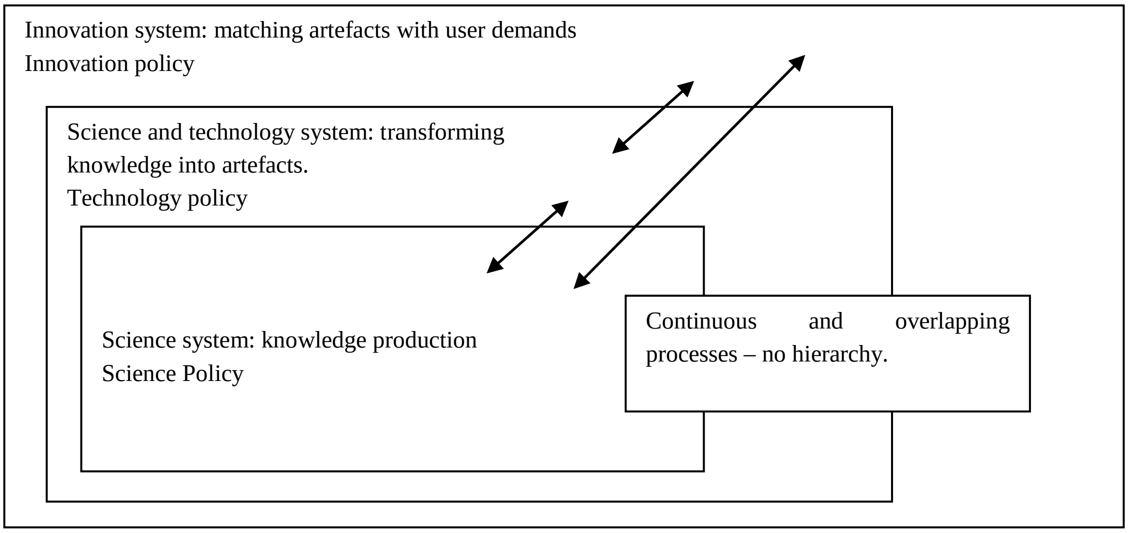

Figure 2: Dimensions of innovation systems and policy – developed from (Lundvall & Borrás, 2005; Pavitt, 2005)**.**

3 Foresight

In the complexity of the learning economy governments, universities and firms must make decisions about investments in innovation in an increasingly unpredictable environment. At the same time (public) knowledge production is increasingly exposed to tighter budgets (relative to number of investment areas) and public governance which implies accountability and social returns on investment in science. The situation has generated an increased demand for information about how to distribute scarce resources and prioritize knowledge areas to support innovation, which involves qualified anticipation of future parameters for international competitiveness (Georghiou, 2001). Hence, as the learning economy has become more pronounced the number of foresights has increased continuously since the 1980s (Butter, Brandes, Keenan, & Popper, 2008).

The purpose of foresight is not to predict the future but to imagine alternative futures and their consequences, and on that basis engage in informed decision-making. Foresight thus rests on two key assumptions: (i) that the future is not laid out, (ii) and that decisions and actions taken today can affect the future. Foresight can be defined as a systematic, participatory, future-intelligence-gathering and medium-to-long-term vision-building process aimed at enabling present-day decisions and mobilizing joint actions (EFP, 2012). It is important to note that in this perspective foresight is perceived as a process where new insights emerge and capabilities are built (in participants) rather than a tool for prediction (Wiek, Binder, & Scholz, 2006). Moreover, it is important to stress that the essential rationale and motivation for (public policy) foresight is ultimately social and economic development by linking science and technology policy more effectively to wealth creation (Martin & Johnston, 1999) – with innovation as the main lever.

The understanding and content of foresight is has changed over time. These changes have been motivated by changing rationales for actually doing foresight and broadening scope of application areas, which in turn has generated a vast diversity in methods applied in foresight exercises. These factors have coevolved and made it possible to identify different generations of foresight (Miles et al., 2008; Schlossstein & Park, 2006; Tegart & Johnston, 2004). Before reviewing the generations it is helpful to uncover the roots of foresight because these are explanatory factors of the latter changes.

3.1 Roots of foresight

(1) Foresight is rooted in an American **technological forecasting** (or simply forecasting) tradition which was mainly developed in relation to strategic military studies at the RAND corporation in the USA during the 1940s and 1950s (Jantsch, 1967). Technological forecast is often associated with making probabilistic assessments about the future which makes accuracy a critical parameter (P. D. Andersen & Rasmussen, 2012). The fact that these methods did not predict the oil crises of the 1970s generated significant skepticism about the usefulness and validity of forecasting (particularly in periods of radical change) which in turn stimulated the development of other approaches (Miles, 2010).

(2) According to Miles (2010) foresight is also rooted in a European tradition of **futures studies** (Bell, 2003, 2004) established in the 1960s and 1970s. The field of futures studies tends to be dominated by professionals from social sciences and the humanities and is seen as an art involving creative and imaginative thinking and acting (Martin, 1995). Moreover, the early futures studies tradition was characterized by a pessimistic and critical point of view on the future and on technology, and that this partly formed the foundation of the tradition of technology assessment. Compared to forecast, futures studies were more focused on stimulating public debate while forecast was an instrument for concrete decision making (Miles, 2010).

(3) **Technology assessment** is intended to analyze risk, costs and benefits related to the introduction of a specific technology or the management of it, and convey this information to the public, politicians and other decision makers. Citizen participation in discussions about desirable developments and types of technologies is an important aspect of technology assessment. This distinguishes technology assessment from forecast and futures studies that both tend to be elitist and expert-focused (P. D. Andersen & Rasmussen, 2012).

(4) The inspiration for the first formulation of **foresight** partly came from Japan around 1980 (as did innovation studies stimulus) whose 'technological forecasting' was markedly different from what was going on elsewhere. Martin (2010) characterizes it as: (i) not only involving a few experts but thousands of scientists, industrialists, governments officials and others; (ii) it considered the demand side of future economic and social needs; (iii) it combined top-down and bottom-up elements; (iv) and it emphasized process-benefits. This led Irvine and Martin (1984) to propose the term foresight as a strategic forward-looking technology analysis to be used as a public policy tool in priority setting in science and technology (Irvine & Martin, 1984). It was defined in opposition to 'hindsight' – understood as analysis of the historical process and origins of certain important technological innovations.

Since Irvine and Martin (1984) foresight has established itself as a field of practice in both public policy making and in corporate strategic planning, and more recently as a scientific discipline. It has been characterized by increasing conceptual broadening and diversity. The latter reflects experimentation with and application of diverse rationales as foundation for foresight. It has become more participatory, complex and is applied at multiple levels and in numerous dimensions (Luke Georghiou, Harper, Keenan, Miles, & Popper, 2008).

3.2 Generations of foresight

With a focus on national foresights in the United Kingdom Miles, Harper, Georghiou, Keenan, and Popper (2008) have identified broad changes in the understanding and practice of foresight that they translate into five generations of foresight. The changes are predominantly motivated by the changes in the underlying rationale for doing foresight. Rationales for foresight have co-evolved with the progressing understanding of the causalities between science, technology, innovation and economic development that has taken place in innovation studies (Smits, Merkerk, Guston, & Sarewitz, 2010).

3.2.1 1st generation – science foresight

The 1st generation of foresight basically consists of technological forecasting, which is the domain of technological experts with focus on natural science and engineering as main disciplines. It is concerned with accuracy of predictions which is understood as an essential part of a science and technology transfer (to society) policy (Georghiou, 2001). The latter reflects a linear model of innovation. Moreover, it reflects an understanding of both innovation and the future as being phenomena that can be predicted. The core rationale for this type of foresight is based on the linear model of innovation, and leads to 1st generation innovation policy with a strong focus on basic science (science policy). Thus, it is suitable to label this practice as 'science foresight'.

3.2.2 2nd generation – technology foresight

The 2nd generation of foresight is characterized by the recognition that the demand for technology must be taken into account in order to successfully transfer scientific knowledge to industry. Representatives from industry are now included among the key actors in the foresight process along with scientists, and actors who are able to bridge the gap between them (Georghiou, 2001; Miles et al., 2008). The changes from the 1st generation of foresight to the 2nd correspond to the progress made in innovation studies conceptualized as the demand-pull model and parts of the couplings model of innovation. The latter reflects the move towards technology policy, and we can label this practice 'technology foresight'.

3.2.3 3rd generation – towards a systems approach

The 3rd generation model is characterized by a 'broadening' of the market perspective by inclusion of a wider set of actors. Its emergence was inspired by foresight activities in Japan where especially the use of bottom-up inputs and process benefits were noted (Martin, 1995; Miles, 2010). Insights from innovation studies implied that foresight practitioners started to take onboard a more complex and non-linear view of innovation[7]. It was recognized that there were insufficient 'bridging organizations' in the socio-economic system, and foresight began to be seen as an arena for making the necessary network connections (Miles et al., 2008). The latter was the first sign of a systems approach which implied a broadening of the actors that could be considered relevant to include in foresight. Hence, 3rd generation foresight adds social stakeholders such as voluntary organisations, consumer groups, pressure groups etc. It also increasingly emphasized socio-economic problem solving as an organizing principle rather than scientific opportunities (Georghiou, 2001). These changes imply that the policy ideal moved towards a systemic ideal and closer to what we have described as 'innovation policy'.

The 3rd generation model was formulated in the mid 1980s and gradually evolved throughout the 1990s. In 1999 the innovation-system approach rationale was explicitly linked to foresight as a tool for 'wiring up' innovation systems by stimulating, extending and deepening interactions (Martin & Johnston, 1999). Even though a general systems rationale emerged the link between the innovation-system approach and foresight was, and still appears, embryonic. Still, the change of emphasis implied that foresight was increasingly seen as a process of linkage and vision building (process benefits) and less as a predictive planning tool (Cariola & Rolfo, 2004).

3.2.4 4th and 5th generations – increasing diversity, complexity and uncertainty

Even though the broad fault line between a systemic and non-systemic perception of science, technology and innovation is located between the 2nd and 3rd generations of foresight Miles et al. (2008) have further identified 4th and 5th generations of foresight that unfolded in the 2000s.

In the 4th generation foresight starts to have a 'distributed role' which implies that more diverse type of organizations are conducting foresight, and that more diverse stakeholders are identified as relevant participants. It takes on a coordinating role for multiple stakeholders and activities. Moreover, multiple organizations finance or perform foresights according to own needs and interest[8].

The 5th generation covers a diversity of foresights levels, locations, dimensions, methods, design and rationales. Often (at a national level) they are concerned with: (i) molding structures or actors within science, technology and innovation; and (ii) the science and technology dimension of broader social or economic issues. The latter can also be conceptualized as a focus on the (S&T dimension of) Grand Challenges[9]. The increasing conceptual broadening and diversity of foresights

---

[7] It is worth noting that Irvine and Martin were located at SPRU (UK) which was also a center of excellence for innovation studies in the 1970s and 80s and which served as a cradle for the innovation-system approach.

[8] This point must be understood as stemming from a UK context which started as singular and national-level public foresights, and then gradually was performed by a range of actors.

[9] The issues covered by the term 'grand challenges' include various, mainly supra-national, concerns around e.g. the environment, food security and resource depletion that are difficult or even impossible to solve by single agencies or through rational planning approaches. The link to innovation policy comes from a political desire of reorienting public-funded science to address these challenges, and it thus functions as a prioritizing tool. By this policy makers (mainly in Europe) hope to excel in science, solve global problems and stimulate economic growth (Cagnin, Amanatidou, & Keenan,

reflects experimentation and coexistence of diverse rationales. This implies that current foresight practice has gone well beyond what is conceptulized as technology foresight (Butter et al., 2008) wherefore the broader term ‘foresight’ is more appropriate.

Another feature of the 2000s is the explicit emergence of a systems approach to foresight[10] which inter alia argues that foresight shouldn’t understand phenomena as separated from their historical, spatial and social context (Saritas, 2011). Though profound, the work by Saritas (2011) is tentative and mainly about the general nature of complex systems without referring to the innovation-system framework. Others have addressed the obvious couplings between innovation systems and foresight, but they have mainly focused on how foresight can contribute to innovation-system analysis (Alkemade et al., 2007; Cagnin et al., 2011; Martin & Johnston, 1999) while we are interested in how the innovation-system framework can contribute to foresight. Some have moreover explored practical applications of an integrated framework of innovation-system analysis and foresight (Dachs & Weber, 2010) but without addressing implications of integration of the theoretical roots. Hence, even though a systems or an innovation-system approach has come to dominate the general thinking about innovation within the foresight community (Weber, Havas, & Schartinger, 2011), the conceptual linkages are still immature/underdeveloped.

Above we have presented a historical review of the evolution of foresight, and indicated that it has been inspired by results achieved in innovation studies. In general the five generations of foresight models should be understood as complementary and coexisting ideal types that most likely do not exist in pure form. Still, they reflect a trajectory of development within foresight which reflects a shift from a linear perception of innovation towards a systemic framework. This shift is far from over, though, which is exemplified by that foresight practitioners tend to overestimate the power/impact of foresight as a result of underestimating the complexity of innovation (Eriksson & Weber, 2008). This implies that several research frontiers/gaps within foresight reflect that it is gradually incorporating the insight that innovation is a systemic, context-dependent, complex, uncertain and interactive process. Also, some authors have called for an update of foresight rationales because it is currently lacking behind the developments in social science (Barré & Keenan, 2008). The latter constitutes a motivation for suggesting deeper integration with the innovation-system framework.

3.3 Innovation-system foresight

The process of shifting the underlying perception of innovation in foresight generates a number of research challenges within foresight research that would suggest a deeper integration with the innovation-system framework. We will here focus on three specific and one general issue.

2012). The trend is partly motivated by the growing need to justify public research funding and the increasing pressure on universities to comply with their 3rd mission role.

[10] Even though a systems rationale had long since been accepted, the actual systematic application of this insight has only emerged recently.

Firstly, it is increasingly recognized that foresight is highly context dependent such that it influences both the foresight process and its potential impact on innovation activity (Barré, 2002; Cariola & Rolfo, 2004). Foresight is taking on board the insight that innovation dynamics differ markedly across contexts (Dosi, 1988). Foresight must be able to systematically and coherently include such diversity to say anything sensible about innovation. The contextual nature of innovation is being recognized but actual work on this issue is lacking (Schoen et al., 2011). Support can be found in the innovation-system framework. Secondly, it has been argued that foresight should increasingly move from being about priority setting towards being more focused on implementing insights and realizing structural change (Edler & Georghiou, 2007). Lacking (demonstrable) impact of foresight has increased focus on demand in the innovation process (Smits & Kuhlmann, 2004). The argument is that including demand more seriously will increase impact (Georghiou & Cassingena Harper, 2011). In nature, the argument is similar to that of distributed innovation policy. The innovation-system framework, where the user and the quality of demand are equally important to supply of knowledge, can guide foresight on how and why to pay more attention to users. Thirdly, the former points are partly related to that foresight, due to public budgetary strains, has come under increased pressure to focus on solutions for existing problems rather than future problems (P. D. Andersen & Rasmussen, 2012). The innovation-system approach has predominantly focused on understanding the evolution of innovation and identifying current barriers (Bergek, Hekkert, et al., 2008). It can give foresight tools for addressing such issues systematically and try to link current problems with future opportunities.

Besides these specific points, it can be argued that the lack of theoretical underpinnings makes it difficult for foresight to be carried out systematically i.e. in coherence with a theoretical framework to support decisions before, during and after the foresight process. There is for example no theoretically founded reasoning behind delimitation of area of interest, selection of participants, criteria/design for understanding and analyzing the present situation[11]. We argue that the innovation-system framework can supply some founding for such decision making and make it analytically coherent.

The still growing diversity of disciplines, rationales, paradigms, designs, methodologies and approaches contained within the term foresight constitute a jungle full of extremely diverse animals[12]. Moreover, not all are explicitly related to innovation, and few to the innovation-system framework. Hence, there seems to be a need for conceptual clarification. The term 'innovation foresight' has been used occasionally. Porter describes innovation foresight as different from

---

[11] Often SWOT or STEEPV analyses are used but they are though practical not very informative regarding methodology, which hinders consistency and in turn reliability of the framework and methodology. This absence of a theoretical foundation also implies that there isn't developed a convincing and systematic argument for how implementation should be carried out / ensured. All these factors have been mentioned before and are obvious in foresight practice, but they are not established in a coherent theoretical body.

[12] Obviously the diversity found in foresight can be a strength for grasping the diversity of the real world but the balance between diversity and generality is a delicate one. The innovation-system approach contains significant diversity within its framework that leaves some flexibility for adapting the analysis to the object of interest.

science foresight or technology foresight because it demands more attention to socio-economic contextual forces interacting with emerging technical capabilities to affect commercial product and services (Porter, 2010).

Porter's point is that innovation is different from and broader than science and technology, and that users play a more pronounced role. Still, it isn't stressed that these dimensions of an innovation system are interdependent in a systemic way. The latter reflects that not all understandings of innovation are systemic. Thus, there is reason to be conceptually more precise. On this basis we propose the term 'innovation-system foresight' to describe foresight that is explicitly founded in the innovation-system framework[13]. Besides additional clarity, the concept imports the innovation-system approach into foresight which, as argued above, has the potential address a number of research gaps in foresight. The latter will in turn make foresight more analytically and theoretically robust. Furthermore, it is more accurate than 'innovation foresight' because it stresses the systemic and process-like character of both foresight and innovation[14]. Innovation-system foresight could be defined as a "systemic, systematic, participatory, future-intelligence-gathering and medium-to-long-term vision-building process aimed at present-day decisions and mobilizing joint actions in order to improve innovation-system performance" (authors' proposal). The previous literature review and current proposal imply that we can make interrelated distinctions between science, technology and innovation policy; between science, technology and innovation foresight; between generations of innovation models; and between generational models of foresight. An overview of these inter-linkages can be seen in the table below.

---

[13] These considerations imply that even though innovation-system foresight should be pursued science and technology foresight are complementary and valuable elements – if they are designed to pay attention to interactions between the science, technology and the innovation (are systemic). Otherwise, they can be everything from unproductive to harmful for innovation. Also, as foresight has evolved in direction of innovation-system foresight (4-5 generation) process benefits have become increasingly more important than product outputs as for example a list of priorities in science and technology. Such lists are still relevant but they should be derived an innovation-system foresight. A priority list without this embedding in a larger process is not valuable.

[14] Foresight is often defined as systematic but it is important to note that being systematic doesn't imply being systemic. We thus emphasize that the word systemic ought to be clear from the definition of innovation-system foresight.

	Description of foresight generations	Conceptual rationale: understanding of innovation	Type of innovation policy	Structure/design	Label
1	mainly forecasting	The science-push model of innovation	Science policy	Mainly expert group driven. elitist	Science foresight
2	Emphasizes matching of technological opportunities with market and nonmarket (environment and social issues).	The demand-pull and couplings model	Technology policy	Increasingly involving firms and policy makers	Technology foresight
3	Signifies an enhancement, or broadening, of foresight's market perspective by inclusion of a broader social dimension that involves concerns and inputs from a broad range of social actors.	The demand-pull and couplings model The integrated model of innovation	Technology policy Innovation policy	Increasingly involving socio-economic actors, more inter-disciplinarily	Foresight
4	Foresight becomes distributed and broadened in scope. Intensifies characteristics of 3rd generation.	The demand-pull and couplings model The integrated model of innovation The systems model	Innovation policy	Increasing diversity in terms of actors, levels, goals and designs	Foresight
5	Foresight becomes concerned with science and technology **systems perspective** and (or because of) increasing orientation towards solving societal challenges (grand challenges)	The linear model of innovation. The demand-pull and chain-linked model The integrated model of innovation The systems and networking model Innovation-system approach	Innovation policy	Increasing diversity in terms of actors, levels, goals and designs	Foresight
Proposal: Focus on demand for knowledge, user-producer interaction, context factors and diversity in innovation dynamics.		Innovation-system approach	Systemic Innovation policy	System delimitation and nature structures design.	Innovation-system foresight

Table 2: Conceptual linkages (developed by authors).

4 Discussion: implications of Innovation-system foresight

A foresight can be described as consisting of three main phases: planning, execution and implementation. Each phase contains a number of steps as can be seen from figure 3[15]. The consequences of innovation-system foresight are direct in the planning phase and mapping the present and indirect for the remainder of the foresight. Therefore we will here discuss preliminary implications for: goal of foresight, system definition/boundaries, participation and mapping of the present. We will argue that the innovation-system framework can function as a focusing device for the design and process of foresight. One could argue that a horizon scanning not founded in an analytical framework (analytical glasses) would essentially be blind. Also, when one needs to define opportunities, threats, or bottlenecks one needs a base for coherently distinguishing between relevant and irrelevant factors. Hence, focus is not on impacts for methods or techniques of foresight but on conceptual design.

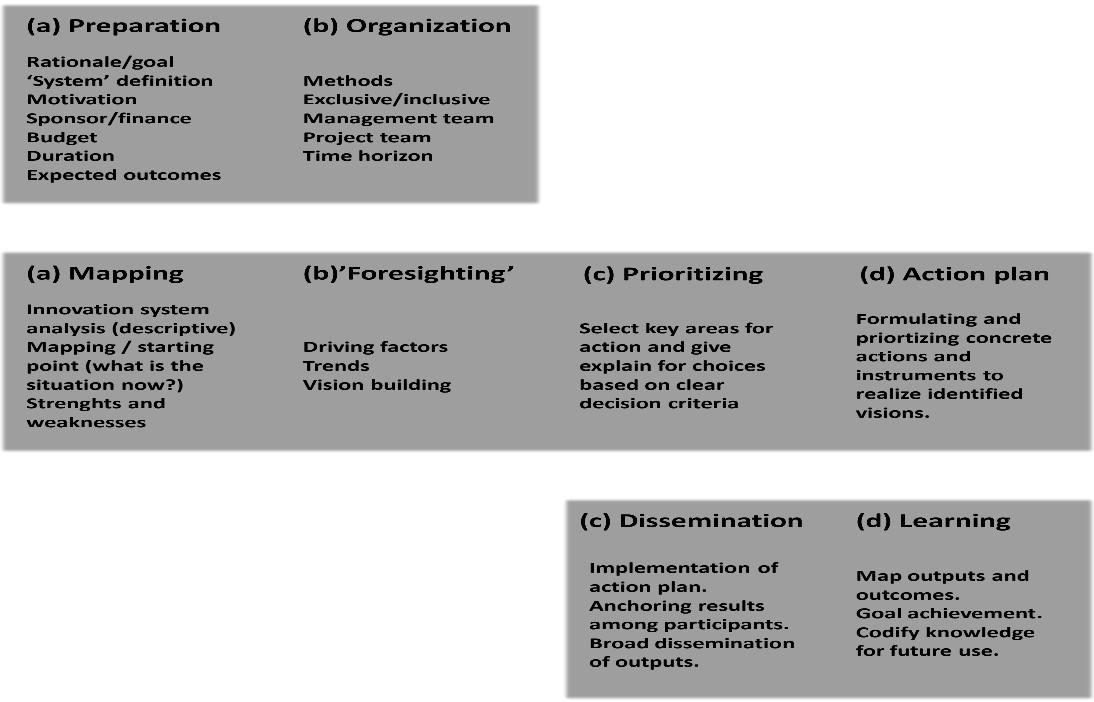

Figure 3: Phases and steps in foresight – adopted and modified from (P. D. Andersen & Rasmussen, 2012)

4.1 Goal of foresight

According to Barré and Keenan the most common goals of foresight are: (1) Exploring future opportunities so as to set priorities for investment in science and innovation activities; (2) Reorienting the Science and Innovation System. This goal is related to priority setting but goes further. In such cases, there may have been a preliminary diagnosis that the science and innovation

[15] It has been modified from general illustrational model of foresight to reflect ideas of innovation-system foresight.

system does not match the needs of the country; (3) Demonstrating the vitality of the Science and Innovation System. In this context foresight becomes a shop window to demonstrate the technological opportunities that are available; (4) Bringing new actors into the strategic debate. A growing tendency is the use of foresight as an instrument to broaden the range of actors engaged in science and innovation policy. One example is the inclusion of social stakeholders or even sections of the general public; (5) Building new networks and linkages across fields, sectors and markets or around problems (Barré & Keenan, 2008). A foresight can have one or several of these objectives which reflects diversity of theoretical foundations.

From the perspective of innovation-system foresight it is possible to establish a hierarchy between the goals mentioned and eventually establish channels of causality between them. The most crucial objective of innovation-system foresight is to 'strengthen' the innovation system which involves building, transforming or reorienting the system by removing barriers to and promote learning and innovation activities. Building new networks and linkages, bringing new actors into the strategic debate, mapping (demonstrating) the' vitality' of the Science and Innovation System, and exploring future opportunities to set priorities for investment in science and innovation activities, are all instruments/means for achieving improvement of an innovation system. These causalities can be illustrated as in figure 4. This implies that in order to be meaningful these instruments must be understood and designed as embedded in an innovation system – the systemic perspective must be applied.

Figure 4: Hierarchy between goals of foresight (developed by authors).

4.2 System definition: boundary setting

According to our knowledge there is in foresight no agreed-upon method for setting system boundaries and thus deciding which factors are external and internal. This is problematic for developing a systematic foresight method based in theory, and for comparison between and generalization of foresight exercises[16]. The setting of initial boundaries influences choice of methodology, data collection and stakeholder involvement in subsequent steps in the foresight process, and is thus a crucial step.

[16] One could further argue that the latter is a precondition for cumulative scientific progress.

Innovation-system foresight should follow the definition innovation system as the organizing principle for setting boundaries. The system should include the elements and relationships which interact in the production, diffusion and use of new, and economically useful knowledge. The main point here is to have basic principles (based in theory) for how to set the boundaries, and explicitly argue for why they were decided as they were. There is flexibility in and debate about how such boundaries are decided which is reflected by the diversity of innovation-system types (RIS, TIS, SSI and NIS). Still, embedded in these system types and the discussions around them is the accumulated knowledge about how to best understand innovation in certain contexts which can be valuable to foresight. Since innovation systems are open, interdependency and interaction between system levels and dimensions must be at the centre.

4.3 Participation: diversity and volume

Which actors are considered relevant is closely related to where the system boundaries are set. Since we are considering an innovation system, system transformation requires distributed policy which in turn requires (meaningful) participation of all key stakeholders. In general it can be said that one should make sure that those who are responsible for making the decisions necessary for achieving the desired change are involved throughout the foresight process such that they feel a sense of ownership of its results (Cagnin, 2011). If the goal is innovation-system transformation, an expert-based foresight will be insufficient – even if systemic. Innovation-system foresight is more in line with a 'inclusive foresight' where actors in the innovation system are mobilized (Loveridge, 2005). Hence, innovation-system foresight is both systemic and distributed.

We can distinguish between diversity and volume of participants. Diversity refers to representation of elements, actors and relationships relevant for innovation processes in a given system (we will explore the further in the next section). Volume refers to degree of representation. The larger the number of participants, the more robust the output may be due to the increased diversity of and competition between ideas. A balance must be found in any concrete case. The main point here is that because actors are seen as the primary agents of change innovation-system foresight must be 'inclusive' (Loveridge, 2005) to be transformational.

4.4 Mapping the present

According to our knowledge there is in foresight no agreed-upon method for analyzing the present and give a deep understanding of the system for which foresight will be carried out. SWOT and STEEPV analyses are often used but they are not based in a coherent theoretical framework nor do they give explicit guidelines for analysis. This hinders consistency and in turn reliability of the framework and methodology. Moreover, these frameworks are not developed to grasp innovation processes, and are thus weak in this respect. It is therefore an important step because the quality of any foresight will depend on the quality of the initial mapping exercise. Innovation-system foresight demands analysis of the innovation system's current state with focus on barriers and opportunities for innovation. The processual nature of evolutionary analysis implies that the present can only be understood by understanding how we arrived there (Langlois, 1986). Complementary historical analysis will most likely be required. The issues identified could appropriately be used as organizing topics for the further foresight process.

The 'functional approach' to innovation systems is very useful as an operational framework for analyzing the present (Bergek, Hekkert, et al., 2008; Bergek, Jacobsson, & Sandén, 2008; Jacobsson, 2004; Jacobsson & Bergek, 2007, 2011). Its usefulness stems from that the approach contains a relatively well-specified guide map for conducting innovation-system analysis which contains tools for grasping synergies between various innovative activities. The basic ideas are summarized in figure 5. The first step is to define the innovation system of interest on the basis of inter alia research objective, breadth and depth, and spatial domain. The second step is to identify structural components of the system such as actors, networks and institutions. The third step is to map the key functions of the system. Fourth and fifth steps imply assessing the functioning of the system, and identify inducement and blocking mechanism. This information can in turn be used for formulating policy to improve the system (step six).

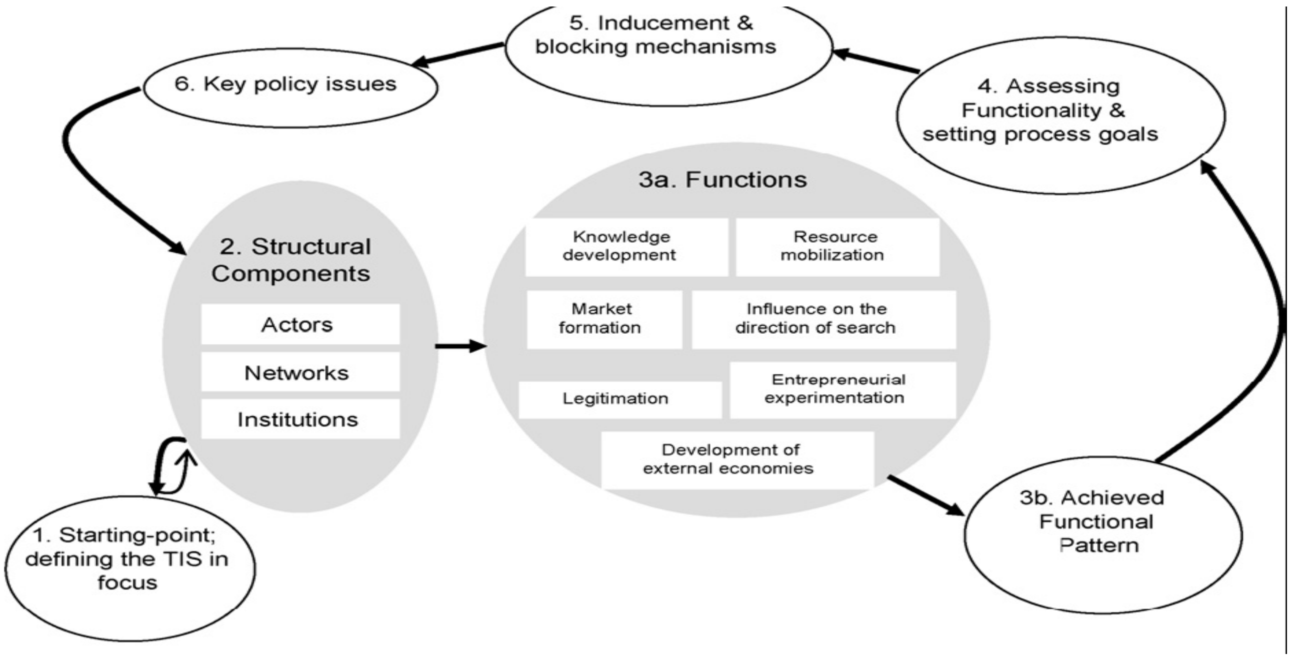

Figure 5: mapping the present (Bergek, Jacobsson et al. 2008).

In contrast to some earlier work in innovation-system research the functional approach is more focused on *what is going on* – the functions or processes – within systems rather than their structural and institutional features (Bergek, Jacobsson et al. 2008). The latter is accommodated by an analytical distinction between components (actors, networks, infrastructure and institutions) and processes in the system, which also implies a distinction between structural and process dynamics[17] (Jacobsson and Bergek 2007). On the basis of a literature survey of past research using the

[17] It is important to note that the distinction is analytical and not empirical. In any specific context a complete separation between changes in components and ongoing activities would not be possible.

innovation-system approach the authors identify seven key functions that is central to performance of an innovation system. They acknowledge that the list of key processes is not finite, and should be applied with open-mindedness with respect to that contextual conditions always differ to some extent. Moreover, the authors focus on technological innovation systems but the analytic framework can in principle be applied to any type of innovation system.

This mapping will serve as a basis for foresighting in the following steps. How the details of the analysis should be done is beyond the scope of this paper.

5 Concluding remarks

The brief reviews of innovation studies and foresight research illustrated that changes in the two areas have co-evolved over the years with foresight importing the dominant understanding of innovation from innovation studies with a time lag. Currently foresight is in a catching-up process vis-à-vis innovation studies – more specifically with incorporating the implications of a systemic understanding of innovation. The latter is one reason for considering a closer integration between foresight and the innovation-system framework.

We also showed that there are research frontiers within foresight that points to a further integration between the two areas. One prominent reason is the search for theoretical foundations for foresight to which we have recommended moving in direction of innovation-system foresight. By integrating further with the innovation-system framework, foresight is able to move towards firmer theoretical underpinnings which in turn allow it to become more analytically coherent. Also, experience with foresight shows that taking into account idiosyncratic contextual factors (institutions, infrastructure, geography, climate, history, etc.) and the demand-side in innovation would yield significant improvements. We have illustrated that the innovation-system approach have tools available for addressing these needs that can be imported.

We have proposed the concept of innovation-system foresight as a natural next step in the communication between the innovation-system approach and foresight. We considered four preliminary implications. Firstly, the goal of foresight is innovation-system transformation (improvement). Secondly, the innovation-system approach gives foresight a framework for analytically setting the boundaries for the system of interest, which has otherwise been done in an ad hoc fashion. Thirdly, because innovation-system actors are seen as agents of change and because systemic innovation policy must be distributed, innovation-system foresight must be inclusive. Inclusiveness should be organized according to the elements, actors and relationships that affect learning and innovation in the system of interest. Identifying these elements and actors is the first step in the innovation-system analysis. Fourthly, the innovation-system framework can supply foresight with an innovation-oriented analytical framework for mapping and understanding the present situation, which will serve as a basis for foresighting activities. There are huge diversity and ad-hoc solutions in mapping exercises in foresight. Even though such diversity can be seen as a strength, it complicates comparison, generalization and ultimately analytical progress. We have suggested the innovation-system framework as a basic, analytically coherent framework for understanding innovation dynamics (in the case the functional approach to innovation systems).

Our considerations are of theoretical nature and the implications sketched concern the perception of foresight and the planning of foresight. Still, there are other less direct implications. Since the goal of innovation-system foresight is innovation-system transformation, actual change is a criterion for success which makes the (policy) implementation step crucial. This is an area where the innovation-system framework doesn't have much to say except that it is very important.

The innovation-system foresight process must cover the interdependent dimensions of science, technology and innovation, and identify the synergies and barriers to their interaction. This must be done with equal attention to users and producers of knowledge, and context parameters. Representatives for all elements, actors and relationships of importance for innovation and learning should be included in the foresight process in reasonable volume. In its core, innovation-system foresight carries a critique of both science foresight and technology foresight (even if systemic), because these setups will find it difficult to identify actors in the demand side with whom to interact. The absence of concrete recipients or users of technological developments undermines the effectiveness of foresight by (a) removing the possibility of interactive learning and feedback loops, and (b) by not enrolling down-stream agents of change that are needed for achieving (sustainable) innovation-system transformation because they are able to block later developments. Still, there are situations where a 'technological innovation-system foresight' is relevant. It will mainly concern technologically radical innovations. This discussion is a point for further research.

Furthermore, the focus on demand that we suggest is different from the demand-focus related to the notion of grand social challenges. Consider two foresights. One consists of an expert group which analyzes which technologies will be critical for international competitiveness in 20 years. Another consists of a group of experts analyzes which social needs will dominate in 20 years, and subsequently which technologies will be in demand due to the latter. Ontologically speaking, the two foresights are not so different. Both processes are exclusive and non-transformational with respect to the innovation system. They analyze the demand side but do not include it. In innovation-system foresight neither scientific progress nor technological R&D can generate ready-made 'optimal' innovations regardless of how detailed an analysis of future demand is made. Only solutions that match technological opportunities, user competence and preference, and context idiosyncrasies can be considered desirable/sustainable[18]. The latter requires inclusive processes of interactive learning and vision building.

[18] One may argue that the focus on Grand Social Challenges stems from the increased pressure on public science to yield higher social returns by addressing social problems. It does not stem from the insight that demand-side inclusion in long-term policy-making processes is needed to make it effective.

The arguments presented in this paper merely constitute a first tentative step towards initiating a constructive dialogue between foresight and the innovation-system approach.

We have not discussed any implications for foresight methods but the centrality of interactive learning may suggest that face-to-face interaction may be a crucial element in achieving shared visions and in turn effective distributed policy. Another implication is that the type of foresight suggested requires additional skills from foresight managers. Conducting the innovation-system analysis demands skilled efforts, and foresighting on the basis of its outcome, will be a complex task. The paper points toward several areas of future research. One is to develop in more detail how to actually do the innovation-system analysis and how to integrate the results with the foresighting activities. Also, implications for foresight methods can be explored further. The development of systemic methods (Saritas, 2011) seems a fruitful path to follow.

6 Literature

Ahlqvist, T., Valovirta, V., & Loikkanen, T. (2012). Innovation policy roadmapping as a systemic instrument for forward-looking policy design. *Science and Public Policy*, 1–13. doi:10.1093/scipol/scs016

Alkemade, F., Kleinschmidt, C., & Hekkert, M. (2007). Analysing emerging innovation systems: a functions approach to foresight. *International Journal of Foresight and Innovation Policy*, *3*(2), 139–168. Retrieved from http://inderscience.metapress.com/index/3np1b07c49wp9y9r.pdf

Andersen, A. D. (2011). *Innovation systems and natural resources – the case of sugarcane in Brazil*. Aalborg University, Denmark.

Andersen, P. D., & Rasmussen, B. (2012). *Fremsyn: Metoder, praksis og erfaringer*. Copenhagen. Retrieved from http://en.fi.dk/

Arthur, W. B. (1994). *Increasing Returns and Path Dependence in the Economy*. The Univeristy of Michigan Press.

Arthur, W. B., Durlauf, S., & Lane, D. (1997). Introduction. In W. B. Arthur, S. Durlauf, & D. Lane (Eds.), *The Economy as an Evolving Complex System II*. Reading, Massachusetts: Addison-Wesley.

Asheim, B. T., & Gertler, M. (2005). The geography of innovation: regional innovation systems. In J. Fagerberg, D. Mowery, & R. Nelson. (Eds.), *The Oxford handbook of innovation*. Oxford University Press, USA.

Barré, R. (2002). FORESIGHTS AND THEIR THEMES: ANALYSIS, TYPOLOGY AND PERSPECTIVES. *THE ROLE OF FORESIGHT IN THE SELECTION OF RESEARCH POLICY PRIORITIES - CONFERENCE PROCEEDINGS*. Seville, Spain.

Barré, R., & Keenan, M. (2008). Revisiting Foresight Rationales: What Lessons from the Social Sciences and Humanities? In C. Cagnin, M. Keenan, R. Johnston, F. Scapolo, & R. Barré (Eds.), *Future-Oriented Technology Analysis - strategic Intelligence for an Innovative Economy*. Springer.

Bell, W. (2003). *Foundations of Futures Studies: History, Purposes, and Knowledge* (p. 390). Transaction Publishers.

Bell, W. (2004). *Foundations of Futures Studies: Values, objectivity, and the good society* (p. 392). Transaction Publishers.

Bergek, A., Hekkert, M., & Jacobsson, S. (2008). Functions in innovation systems: A framework for analysing energy system dynamics and identifying goals for system-building activities by entrepreneurs and policy makers. *Innovation for a low carbon economy: economic, institutional and management approaches*, 79.

Bergek, A., Jacobsson, S., & Sandén, B. a. (2008). "Legitimation" and "development of positive externalities": two key processes in the formation phase of technological innovation systems. *Technology Analysis & Strategic Management*, *20*(5), 575–592. doi:10.1080/09537320802292768

Boulding, K. E. (1981). *Evolutionary Economics*. London: Sage Publications.

Butter, M., Brandes, F., Keenan, M., & Popper, R. (2008). Editors' introduction to the European Foresight Monitoring Network. *foresight*, *10*(6), 3–15. doi:10.1108/14636680810918559

Cagnin, Cristiano. (2011). Aspects to consider when designing foresight processes. *Foresight International Seminar: from theory to practice*. Brasilia: CGEE.

Cagnin, Cristiano, Amanatidou, E., & Keenan, M. (2011). Orienting Innovation Systems towards Grand Challenges and the Roles that FTA Can Play. *Fourth International Seville Conference on Future-Oriented Technology Analysis (FTA)*.

Cagnin, Cristiano, Amanatidou, E., & Keenan, M. (2012). Orienting European innovation systems towards grand challenges and the roles that FTA can play. *Science and Public Policy*, *39*(2), 140–152. Retrieved from http://spp.oxfordjournals.org/content/39/2/140.full

Cariola, M., & Rolfo, S. (2004). Evolution in the rationales of foresight in Europe. *Futures*, *36*(10), 1063–1075. doi:10.1016/j.futures.2004.03.010

Carlsson, B., & Stankiewitz, R. (1995). *Technological systems and economic performance: the case of factory automation*. Dordrecht: Kluwer Academic Publishers.

Cooke, P., Uranga, M. G., & Etxebarria, G. (1997). Regional innovation systems: Institutional and organisational dimensions. *Research policy*, *26*, 475–491. Retrieved from http://www.sciencedirect.com/science/article/pii/S0048733397000255

Cooper, R. G. (1980). The Performance Impact of Product Innovation Strategies. *European Journal of Marketing*, *14*(5), 5–54. doi:10.1108/EUM0000000004787

Dachs, B., & Weber, M. (2010). Sectoral Innovation Foresight Textiles and Clothing Sector Consortium Europe Innovation Watch INNOVA Sectoral. *Europe*, (December).

Dahmén, E. (1989). "Development Blocks" in Industrial Economics. In B. Carlsson & R. G. H. Henriksson (Eds.), *Developments blocks and industrial transformation : the Dahménian approach to economic development*. Stockholm: The Industrial Institute for Economic and Social Research.

Dodgson, M., Gann, D., & Salter, A. J. (2005). *Think, play, do: technology, innovation, and organization*. Oxford University Press, USA. Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Think,+Play,+Do:+Technology,+Innovation,+and+Organization#0

Dosi, G. (1982). Technological paradigms and technological trajectories A suggested interpretation of the determinants and directions of technical change. *Research Policy*, *11*(3), 147–162. doi:10.1016/0048-7333(82)90016-6

Dosi, G. (1988). Sources, procedures, and microeconomic effects of innovation. *Journal of economic literature*, *26*(3), 1120–1171. Retrieved from http://www.jstor.org/stable/2726526

EFP. (2012). *Foresight guide: Impact, Policy and Learning*. Retrieved from http://www.foresight-platform.eu/community/foresightguide/

Edler, J., & Georghiou, L. (2007). Public procurement and innovation—Resurrecting the demand side. *Research Policy*, *36*(7), 949–963. doi:10.1016/j.respol.2007.03.003

Edquist, C., & Johnson, B. (1997). Institutions and Organizations in Systems of Innovation. In C. Edquist (Ed.), *Systems of Innovation*. London: Pinter.

Edquist, C., & Lundvall, B.-Å. (1993). Comparing the Danish and Swedish Systems of Innovation. In R. Nelson & N. Rosenberg (Eds.), *National Innovation Systems: A Comparative Analysis*. Oxford: Oxford University Press.

Eriksson, E. A., & Weber, M. (2008). Adaptive Foresight: Navigating the complex landscape of policy strategies. *Technological Forecasting and Social Change*, *75*(4), 462–482. doi:10.1016/j.techfore.2008.02.006

Fagerberg, Jan, Mowery, D. C., & Verspagen, B. (2009). The evolution of Norway's national innovation system. *Science and Public Policy*, *36*(6), 431–444. doi:10.3152/030234209X460944

Foss, K., & Foss, N. (2002). Authority in the Context of Distributed Knowledge. *Common Knowledge*.

Freeman, C. (1987). *Technology policy and economic performance: Lessons from Japan*. London: Pinter.

Freeman, C. (2003). Preface. In M. Muchie, P. Gammeltoft, & B. Å. Lundvall (Eds.), *Putting Africa first - The making of African innovation systems*. Aalborg University Press.

Fuller, T., & Loogma, K. (2009). Constructing futures: A social constructionist perspective on foresight methodology. *Futures*, *41*(2), 71–79. doi:10.1016/j.futures.2008.07.039

Georghiou, L. (2001). Third Generation Foresight - Integrating the Socio-economic Dimension. *NISTEP Study Material*. Retrieved from http://sciencelinks.jp/j-east/article/200121/000020012101A0613356.php

Georghiou, L., & Cassingena Harper, J. (2011). From priority-setting to articulation of demand: Foresight for research and innovation policy and strategy. *Futures*, *43*(3), 243–251. doi:10.1016/j.futures.2010.11.003

Hayvaert, C. H. (n.d.). *Innovation Research and Product Policy: Clinical Research in 12 Belgian Industrial Enterprises*. *1973*.

Hideg, É. (2007). Theory and practice in the field of foresight. *Foresight*, *9*(6), 36–46. doi:10.1108/14636680710837299

Irvine, J., & Martin, B. R. (1984). *Foresight in science: picking the winners*. Pinter London. Retrieved from http://books.google.dk/books/about/Foresight_in_science.html?id=0NXaAAAAMAAJ&redir_esc=y

Jacobsson, S. (2004). Transforming the energy sector: the evolution of technological systems in renewable energy technology. *Industrial and Corporate Change*, *13*(5), 815–849. doi:10.1093/icc/dth032

Jacobsson, S., & Bergek, A. (2007). A framework for guiding policy makers intervening in emerging innovation systems in "catching up" countries. *European Journal of Development Research*, *18*(4).

Jacobsson, S., & Bergek, A. (2011). Innovation system analyses and sustainability transitions: Contributions and suggestions for research. *Innovation and Societal Transitions*.

Jantsch, E. (1967). *Technological forecasting in perspective*. Paris.

Johnson, B. (1992). Institutional Learning. In B. A. Lundvall (Ed.), *National Systems of Innovation – Toward a Theory of Innovation and Interactive Learning*. London: Pinter.

Johnson, B., Edquist, C., & Lundvall, B.-Å. (2003). Economic development and the national system of innovation approach. *First Globelics Conference, Rio de Janeiro* (pp. 3–6). Retrieved from http://www.globelicsacademy.net/pdf/BengtAkeLundvall_2.pdf

Kline, S. J., & Rosenberg, N. (1986). An overview of innovation. In R. Landau & N. Rosenberg (Eds.), *The Positive Sum Strategy: Harnessing Technology for Economic Growth*. Washington D.C: National Academy Press.

Laestadius, S. (1998). The relevance of science and technology indicators: the case of pulp and paper. *Research Policy*, *27*(4), 385–395. doi:10.1016/S0048-7333(98)00050-X

Laestadius, S. (2000). Biotechnology and the Potential for a Radical Shift of Technology in Forest Industry. *Technology Analysis & Strategic Management*, *12*(2), 193–212. doi:10.1080/713698464

Langlois, R. N. (1986). The new institutional economics: an introductory essay. In R. N. Langlois (Ed.), *Economics as a process*. Cambridge University Press.

Langrish, J., Gibbons, M., Evans, W. G., & Jevons, F. R. (n.d.). *Wealth from Knowledge*. London: Macmillan.

Loveridge, D. (2005). Inclusive foresight. *Foresight*, *7*(3), 31–47. doi:10.1108/14636680510601968

Luke Georghiou, Harper, J. C., Keenan, M., Miles, I., & Popper, R. (Eds.). (2008). *The handbook of technology foresight: concepts and practice*. Edward Elgar Pub.

Lundvall, B.-Å. (1985). Product Innovation and User-Producer Interaction. *Analysis*, (31).

Lundvall, B.-Å. (Ed.). (1992). *National Systems of Innovation – Toward a Theory of Innovation and Interactive Learning*. *Analysis*. London: Pinter.

Lundvall, B.-Å., & Borrás, S. (2005). Science, technology and innovation policy. *The Oxford handbook of innovation*. Oxford University Press Oxford.

Lundvall, B.-Å., & Johnson, B. (1994). The Learning Economy. *Journal of Industry Studies*, *1*(2), 23–42. doi:10.1080/13662719400000002

Lundvall, B.-Å., Joseph, K. J., Chaminade, C., & Vang, J. (Eds.). (2009). *Handbook of Innovation Systems and Developing Countries*. *Learning*. Edward Elgar, Cheltenham, UK. Northhamton, MA, USA. Retrieved from http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1551492

Malerba, F. (2002). Sectoral systems of innovation and production. *Research Policy*, *31*(2), 247–264. doi:10.1016/S0048-7333(01)00139-1

Malerba, F. (2005). Sectoral systems: how and why innovation differes across sectors. In J. Fagerberg, D. Mowery, & R. Nelson (Eds.), *The Oxford handbook of innovation*. Oxford University Press, USA.

Martin, B. R. (1995). Foresight in science and technology. *Technology Analysis & Strategic Management*. Retrieved from http://www.tandfonline.com/doi/abs/10.1080/09537329508524202

Martin, B. R., & Johnston, R. (1999). Technology foresight for wiring up the national innovation system: experiences in Britain, Australia, and New Zealand. *Technological Forecasting and Social Change*, *60*(1), 37–54. doi:10.1016/S0040-1625(98)00022-5

Metcalfe, J. S. (1995). The economic foundations of technology policy: equilibrium and evolutionary perspective. In P. Stoneman (Ed.), *Handbook of industrial innovation*. London: Blackwell.

Miles, I. (2010). The development of technology foresight: A review. *Technological Forecasting and Social Change*, *77*(9), 1448–1456. doi:10.1016/j.techfore.2010.07.016

Miles, I., Harper, J. C., Georghiou, L., Keenan, M., & Popper, R. (2008). The Many Faces of Foresight. In L. Georghiou, J. Harper, M. Keenan, I. Miles, & R. Popper (Eds.), *The Handbook Of Technology Foresight: Concepts and Practice* (pp. 3–23).

Myers, S., & Marquis, D. G. (1969). *Successful Industrial Innovation*. Washington DC.

Nelson, R. (1995). Recent Evolutionary Theorizing About Economic Change. *Journal of Economic Literature*, *38*, 48–90.

Nelson, R., & Rosenberg, N. (1993). Technical Innovation and National Systems. In R. R. Nelson (Ed.), *National Innovation Systems - A Comparative Analysis*. Oxford University Press, USA.

Niosi, J., Saviotti, P., Bellon, B., & Crow, M. (1993). National systems of innovation: in search of a workable concept. *Technology in Society*, *15*(2), 207–227. doi:10.1016/0160-791X(93)90003-7

Nooteboom, B. (2000). Learning by Interaction Absorptive Capacity , Cognitive Distance and Governance. *Journal of Management*, *4*, 69–92.

Patel, P. R., & Pavitt, K. (1994). The Nature and Economic Importance of National Innovation Systems. *STI Review*.

Pavitt, K. (1984). Sectoral patterns of technical change: Towards a taxonomy and a theory. *Research Policy*, *13*(6), 343–373. doi:10.1016/0048-7333(84)90018-0

Pavitt, K. (2005). Innovation processes. In Jan Fagerberg, D. C. Mowery, & R. Nelson (Eds.), *Oxford Handbook of Innovation*. Oxford University Press.

Porter, A. L. (2010). Technology foresight: types and methods. *International Journal of Foresight and Innovation Policy*, *6*(1/2/3), 36. doi:10.1504/IJFIP.2010.032664

Rothwell, R. (1976). Innovation in Textile Machinery: Some Significant Factors in Success and Failure.

Rothwell, R. (1994). Towards the Fifth-generation Innovation Process. *International Marketing Review*, *11*(1), 7–31. doi:10.1108/02651339410057491

Rothwell, R., Freeman, C., Horsley, A., Jervis, V. T. P., Robertson, A. B., & Townsend, J. (1974). SAPPHO Updated: Project SAPPHO Phase II. *Research Policy*, *3*(3), 258–291.

Rubenstein, A. H., Chakrabarti, A. K., O'Keefe, R. D., Sonder, W. E., & Young, H. C. (1976). Factors Influencing Success at the Project Level. *Research Management*, *19*(3), 15–20.

Saritas, O. (2011). Systemic Foresight Methodology. *Forth International Seville Conference on Future-Oriented Technology Analysis (FTA) FTA and Grand Societal Challenges – Shaping and Driving Structural and Systemic Transformations SEVILLE, 12-13 MAY 2011*. Retrieved from http://www.inovita.org/docs/1328291461Ozcan Saritas_Inovita Presentation_111228.pdf

Schlossstein, D., & Park, B. (2006). Comparing recent technology foresight studies in Korea and China: towards foresight-minded governments? *Foresight*, *8*(6), 48–70. doi:10.1108/14636680610712531

Schock, G. (1974). *Innovation Processes in Dutch Industry*.

Schoen, A., Könnölä, T., Warnke, P., Barré, R., & Kuhlmann, S. (2011). Tailoring Foresight to field specificities. *Futures*, *43*(3), 232–242. doi:10.1016/j.futures.2010.11.002

Simon, H. (1983). *Reason in Human Affairs*. Stanford University Press.

Smith, K. (1999). Industrial structure, technology intensity and growth: issues for policy. *DRUID conference on National Innovation Systems, Industrial Dynamics and Innovation Policy, Rebild, Denmark, June 9-12, 1999*.

Smits, R., & Kuhlmann, S. (2004). The rise of systemic instruments in innovation policy. *International Journal of Foresight and Innovation Policy*, *1*(1/2), 4. doi:10.1504/IJFIP.2004.004621

Smits, R., Kuhlmann, S., & Shapira, P. (2010). *The Theory and Practice of Innovation Policy: An International Research Handbook*. Edward Elgar. Retrieved from http://works.bepress.com/pshapira/26/

Smits, R., Merkerk, R. van, Guston, D. H., & Sarewitz, D. (2010). The Role of Technology Assessment in Systemic Innovation Policy. In R. E. Smits, S. Kuhlmann, & P. Shapira (Eds.), *The Theory and Practice of Innovation Policy: An International Research Handbook*.

Sokoloff, K., & Engerman, S. L. (2003). Institutional and non-institutional explanations of economic differences.

Szakasitz, G. D. (1974). The Adoption of the SAPPHO Method in the Hungarian Electronics Industry. *Research Policy*, *3*.

Tegart, G., & Johnston, R. (2004). Some Advances in the Practice of Foresight. *EU-US SEMINAR: NEW TECHNOLOGY FORESIGHT, FORECASTING & ASSESSMENT METHODS-Seville 13-14 May 2004* (pp. 30–46).

Utterback, J. M. (1975). *The Process of Innovation in Five Industries in Europe and Japan*. MIT Press, Cambridge, MA.

Weber, M., Havas, A., & Schartinger, D. (2011). Exploring the potential impact of FLA on national innovation systems. *Forth International Seville Conference on Future-Oriented Technology Analysis (FTA) FTA and Grand Societal Challenges – Shaping and Driving Structural and Systemic Transformations SEVILLE, 12-13 MAY 2011*.

Weber, M., Schaper-Rinkel, P., & Butter, M. (2009). *Sectoral Innovation Foresight*. Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Sectoral+Innovation+Foresight#7

Wiek, a, Binder, C., & Scholz, R. (2006). Functions of scenarios in transition processes. *Futures*, *38*(7), 740–766. doi:10.1016/j.futures.2005.12.003

Winter, S. (1987). Knowledge and Competence as Strategic Assets. In D. J. Teece (Ed.), *The Competitive Challenge: Strategies for Industrial Innovation and Renewal* (pp. 159–184). Cambridge, Massachusetts: Ballinger.

Öner, M. A. (2010). On theory building in Foresight and Futures Studies: A discussion note. *Futures*, *42*(9), 1019–1030. doi:10.1016/j.futures.2010.08.026