Sectoral innovation foresight
- Sector development at the Danish Technical university

Allan Dahl Andersen
DTU Management Engineering
Innovation Systems and Foresight
Technical University of Denmark
Email: adah@dtu.dk
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## 4.1 SECTORAL INNOVATION FORESIGHT IN DENMARK?
1 Introduction

In this working paper I will propose a specific integration between the academic areas of foresight and of innovation-system research based on the concept of interactive learning. I will argue that foresight focused on stimulating innovation can use the innovation-system framework as its main theoretical underpinning with benefit. On the basis of literature reviews of innovation studies and foresight research I identify co-evolving patterns of change over time. These patterns have inspired me to, maybe foolishly, propose the term ‘innovation foresight’ to describe explicit innovation system-based foresight which is helpful to navigate in the great diversity of foresights. Subsequently, I try to apply the tentative framework in analyzing four cases of ‘sector development strategy’ managed by the Danish Technical University (DTU). I conclude that innovation foresight isn’t practiced at DTU. Instead their activities can better be characterized as science foresight or technology foresight based on the rationale of the linear model of innovation without a systemic understanding of innovation.

1.1 Motivation

The motivation for engaging in this work can be divided into a practical and an academic interest.

1.1.1 The practical

The practical motivation for writing this paper is the initiation of a sector development program at the Technical University of Denmark (DTU). DTU is with its basis in natural sciences and technology focused on that its activities contribute to well-being in society, that they are relevant for industry and economic activities, and promotes sustainable development. DTU is therefore in close dialogue with the Danish society and actively engages with areas of the economy that are dependent on technology and knowledge. DTU has recently chosen, amongst other initiatives, to pursue a sector-oriented strategy in this endeavor. One reason behind this decision was the realization that innovation is increasingly an open, distributed and systemic process that involves a range of different actors, institutions, knowledge bases and infrastructures. The latter entails that DTU cannot possibly achieve its goals by focusing exclusively (mainly) on individual organizations and individual firms – instead a system approach is needed. More specifically, a sectoral innovation system approach is needed. This change of emphasis brings forward several new challenges for DTU.

The main intention with the sector development initiative is that DTU in collaboration with business associations and ministries aims to identify and pursue ideas for the development of business sectors, such that DTU in cooperation with these actors and sectors can:

1. Define and promote ‘strategic’ technological areas
2. Point out barriers and opportunities in the ‘framework conditions’ for sectors.
3. Support with counseling about management and optimization
4. Secure the foundations and infrastructure of sectors

The part of DTU’s administration (public sector consultancy – PSC henceforth) that manages the sector development program is not familiar with the (any) theoretical perspectives underlying the new initiative. As part of this project it is my task to assist them by developing a theoretical framework for their activities, communicate with them and evaluate their current practice. As part of the latter I have analyzed their prior and currently ongoing projects of sector development strategy. These will constitute the empirical material of this paper. The main practical question at hand thus is “how should DTU carry out its sector development strategy?”
1.1.2 The Academic

It is possible to identify a range of ‘research gaps’ that justifies exploring fruitful combinations of the foresight discipline and the innovation-system approach.

(1) Theoretical underpinnings

According to Weber, Schaper-Rinkel, & Butter (2009) “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 literature that there is gap between practice and theory in foresight (R. 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).

In this working paper I suggest the innovation-system framework based on the concept of interactive learning as the theoretical underpinnings of foresight in an attempt to narrow the gap between the two areas.

(2) The importance of context

It is increasingly recognized that foresight is highly context dependent; that context parameters influences both the process and its potential impact on innovation activity (R. Barré, 2002; Cariola & Rolfo, 2004). Likewise, innovation studies have shown that the process of innovation and its dynamics differ markedly across firms, sectors, regions and nations (Dosi, 1988). This implies that foresight must take this diversity into account in order to say anything sensible about innovation. The contextual nature of innovation is being recognized but actual work on this issue is largely absent (Schoen, Könnölä, Warnke, Barré, & Kuhlmann, 2011). That innovation is localized both geographically, culturally and cognitively is a main insight from the innovation systems research. Foresight can learn many lessons from the large number of diverse and detail-rich studies of innovation systems.

(3) Including the demand side

There is an increasing focus on the demand-side in innovation policy in Europe which has implications for foresight. Foresight should increasingly move from being about priority setting towards being more focused on implementing insights and realizing structural change (Edler & Georghiou, 2007). The critique of the lacking 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 (Luke Georghiou & Cassingena Harper, 2011) and improve efficiency of innovation (via communication). Still, “Foresight’ most often does not take sufficient notice of the demand for knowledge, existing competences, and the reality and wishes of firms are not emphasized” (Smits, Kuhlmann, & Shapira, 2010). The increased emphasis on demand, is perfectly suitable for the innovation-system approach which sees interactive learning – where demand and supply of knowledge are seen as equally important – as the most central process in economic development (B. A. Lundvall, 1992).

(4) Limited communication between the two disciplines?
According to Smits, Kuhlmann, & Shapira (2010) there is despite obvious common ground hardly any communication between the innovation-system approach and foresight (strategic intelligence). This working paper can be seen as an attempt to participate in the conversation.

1.2 The approach
The point of departure for this report is that innovation must be understood as an interactive learning process which is the micro foundation for the innovation-system approach (B.-Å. Lundvall, Johnson, & Andersen, 2002). Moreover, the analytical tradition pursued here can best be described as an evolutionary, institutional approach to economics (Boulding, 1981; Hodgson, 2008; R. Nelson, 2008). The latter gives direction to my understanding of foresight and of innovation.

The working paper does not include niche management, transition management or the multi-level framework (Geels, 2004). The main reason is lack of time, not lack of relevance. One could argue though, that since my main focus is on innovation in firms the innovation-system framework is the best suitable choice.

In this paper I will mainly focus on the benefits and consequences for foresight from taking the innovation-system framework as its theoretical underpinnings. Focus will thus be on what foresight can learn/gain from innovation-system analysis and not vice versa. I will approach both innovation and foresight from the perspective of public policy. Due to the practical motivation for the project I will be inclined to focus on the sectoral perspective in innovation systems though my working premise is that systems share inherent characteristics independently of scale, territory and sector.

Because this is part of a larger report, this working paper will take on a partly report-like character with extensive reviews of the literature that would not be so significant in a research-paper version. Also, the audience is thought to be researchers from both the innovation system and from the foresight discipline (mainly) which implies that some points are spelled out in relatively great detail.

1.3 Research questions
Both parts of my motivation constitute a main research question.

The academic motivation and the research gaps identified can be addressed by asking “What can foresight learn from the innovation-system approach?” In order to approach this questions I must answer the following sub-questions: “What is the innovation-system approach?”; “What is foresight?”; and “What can foresight learn from the innovation-system approach regarding (1) theoretical underpinnings, (2) the importance of context, and (3) including the demand side?

The practical motivation for this work can be addressed by evaluating the current practice at DTU-PSC. The issue can be formulated as the research question “to what extent is innovation foresight practiced in DTU’s sector development program?” To answer the latter question I need to: (a) chose and develop indicators for ’measuring’ innovation foresight, (b) describe how sector foresight is practiced in Denmark, (c) and evaluate whether this practice can be characterized as innovation foresight according to the chosen parameters. At the end of the section I initiate the discussion of why innovation foresight isn’t practiced at DTU - what are the barriers? Is it at all desirable?

These questions will give structure to the working paper.
1.4 Structure
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 will conclude with presenting the innovation-system approach. The purpose is to define a 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 some research in need of work. At the end of the chapter I propose innovation foresight as a term for describing foresight that integrates specific elements (highlighted in research questions) from the innovation-system framework to strengthen foresight concerned with innovation. In chapter 4, I will develop and present a template for evaluating whether a foresight can be characterized as innovation foresight. In chapter 5 I will apply this framework to analyze how DTU-PSC manages the sector development program. Chapter 6 will be the conclusion.
2 Innovation studies

There is something inherently human about innovation in the sense that it is about imagining new and better ways of doing things and to try them out in practice. The world would look somewhat different without this sort of activity – without airplanes, automobiles, telecommunications, and refrigerators, or without agriculture, the wheel, the alphabet, or printing? Obviously, innovation is not a new phenomenon. Still, explicit research of innovation is relatively recent. It only emerged as a separate field in the 1960s. It emerged outside prestigious disciplines and universities mainly under a heading of ‘science studies’ or similar terms. The formation of SPRU (Science Policy Research Unit, Brighton, UK) in 1965 would prove to be critical. From there onwards innovation studies (a broad field) has grown significantly. Research on the role of innovation in economic and social change increased in number of publications and university departments during the 1990s and 2000s. Most are of cross-disciplinary orientation which reflects that innovation can be studied from a range of different perspectives (Fagerberg & Mowery, 2005). I will rely on this field of research in the following chapters.

2.1 What is innovation?

“Innovation generally refers to the creation of better or more effective products, processes, technologies, or ideas that are accepted by markets, governments, and society”.

The economic impact of learning in production often takes the form of innovations that are to be understood as ‘something’ qualitatively novel in its context. Learning is here understood in a broad sense; as a process leading to new knowledge, to new combinations of old knowledge, or to putting old knowledge into new heads (Johnson, 1992). There is a selection mechanism that implies that not all knowledge is equally useful in an economic sense. Therefore not all learning processes leads to innovation, but innovation is not possible without learning activities. If one sees economic development as a process that involves creation of new resources, knowledge and activities, it must necessarily involve innovation – thus innovation and economic development are in fact inseparable concepts. The latter implies that human learning is the main source of economic development, and that to understand development it is necessary to understand the process of innovation.

Innovation can be defined in several ways. It is obviously a rather vague term that can be defined to include many different things. The core of it is that is brings an element of novelty, and thereby diversity, into the economic system. Inventions may take place in various organizations (universities, hospitals, etc) but innovation mainly takes place in firms since they are the main commercial agents in a market economy (Kline and Rosenberg 1985a; Fagerberg 2005). Normally one distinguishes between three steps in an innovation process invention, innovation and diffusion. Invention is having a great idea or discovering a new technology, while innovation refers to the commercialization of invention. Innovation is then followed by a process of diffusion, where the innovation gradually finds broader application. These phases are normally thought to follow a life-cycle pattern with distinct dynamics in each phase. Still, there are some problems in this separation between phases.

(i) First of all the process from invention to innovation is not always straightforward. Some inventions may have been initially made decades or centuries before the find their way to a commercial application, and there is no guarantee that they ever will. Fagerberg (2005) illustrates this with the example of Leonardo da
Vinci who to some extent is accredited with the invention of the airplane in the 15th century, but due to absence of materials, capabilities and a suitable power source, it did not become an innovation until much later. The latter implies that an invention often requires the existence of complementary measures to become an innovation.

(ii) Also, the perception of both invention and innovation as a discrete event is complicated. An invention may, by some, be regarded as an exogenous event, which arrives out the blue. In reality the slogan of Google scholar – standing on the shoulders of giants - probably comes closer to the truth because both inventions and innovations are outcomes of knowledge accumulation that took place prior. Thus, it is dubious to take an invention as starting point for an analysis of innovation, when it in reality is part of a larger process of knowledge accumulation that must also be understood in order to grasp the nature of innovation. A similar aspect concerns that many innovations are continually improved upon – one example is the quality of airplanes. These observations suggest that both invention and innovation are continuous processes, and that inventor and innovator need not be the same actor.

(iii) Likewise the separation between innovation (as an event) and diffusion is complicated because also here I see feedback mechanisms between the spread of the innovation and its initial design. As an innovation is diffused to diverse contexts it must often be adapted in to idiosyncratic environments and thus be changed and redesigned significantly. Also, just the presence of the innovation may give other entrepreneurs ideas about applying it in a context different from the intended, which will stimulate further mutation/alteration. Hence, further innovation/invention often takes place during diffusion processes. Due to the latter, and due to the issue of scale, Nelson and Rosenberg (1993) argue that in terms of economic significance, it is, at least, as relevant to study processes of diffusion as process of invention and innovation. To grasp the diffusion process one can consider the mechanisms involved in the transfer and absorption of knowledge/technology from one actor to another (Cohen and Levinthal 1990). The basic idea is that ‘absorption’ of new knowledge (innovation) to a given context most often requires capability building on behalf of the receiving/absorbing part which, in the case of a transfer, often involves personal interaction with the ‘selling’ part. Thus, in order to obtain knowledge, one must understand it, which requires a process of learning. The more complex the item, the more excessive capability building and interaction will be required. In this process several modifications of knowledge item to context will often take place (Fagerberg and Godinho 2005).

These considerations call for an understanding of innovation as a process rather than as a single event, because it is constantly ongoing. It is a process of knowledge accumulation via learning processes. Learning and capability building does not always lead to innovation but innovation is ultimately seen as an outcome of the latter processes (but also as input to new learning). This perspective is the basis illustrates that it is rarely beneficial to make strict distinctions between science, technology and innovation.

2.2 Innovation through time: review of innovation studies
Since innovation studies emerged and grew in the 1960s a large body of knowledge about innovation has accumulated, and researchers have gradually better understood the nature of innovation. Still, at the same time the ‘mode of innovation’ has changed over time such that researchers in principle have been dealing with a ‘moving target’. Due to research efforts and changing modes of innovation it is possible to identify successive modes or models of innovation (Dodgson, Gann, & Salter, 2005; Rothwell, 1994). I will present these in the following because this illustrates (i) the sources of innovation, (ii) the nature and complexity of
the process, and (iii) how (i) and (ii) have changed over time. The review will end by introducing the concepts ‘the learning economy’, distributed innovation and argue that the innovation-system approach is currently the best available theoretical framework we have for studying and understanding contemporary innovation. The final section will illustrate how the changing understanding of the innovation process have caused fundamental changes in policy rationales behind innovation policy – also here generations can be identified.

2.2.1 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. This changed immediately after the war due to inter alia the role of science in winning the war, and in contributing to the subsequent weapons race and the competition in space technology (B.-Å. Lundvall & Borrás, 2005). The first two decades in the wake of WW2 saw an unseen economic recovery in the USA and Europe which was based on rapid industrial expansion. This involved the emergence of new industries (largely based on new technological opportunities) as semiconductors, pharmaceuticals, electronic computing and synthetic and composite materials This economic expansion was associated with rapid employment creation, increasing GDP per capita, and a consumption boom. The public opinion was in general positive towards the role of science in society and industrial innovation - they were seen as able to deliver solutions to the problems of society. 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. This model of innovation is known as the linear model or the ‘technology push’ model. The core assumption in these was that “more R&D in resulted in more successful new products out”. With one or two notable exceptions, little attention was paid to the transformation process itself or to the role of the marketplace in the process” (Rothwell, 1994).

2.2.2 2nd generation – the demand-pull model
At the beginning of this period 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 technologies and not 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 – as the market – played a much more prominent role. Here the market was seen as a cradle for ideas that could orient research efforts (R&D) which consequently was given a merely reactive role. On this basis the 2nd generation or ‘market pull’ innovation model was launched (Rothwell, 1994).

2.2.3 3rd generation – the couplings model
The 1970s were a period of economic crisis in the form of two oil crises, high inflation, growing unemployment (stagflation) and thus a decrease in aggregate demand growth. Consequently production capacity exceeded the demand for goods. In this context 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. At this time a
number of detailed empirical studies of the innovation process were published\(^1\). These basically found that both the science-push and the market pull models were extreme and atypical examples of the innovation process. Instead the studies showed that innovation most often is a process of interaction between technological opportunities and market needs. These results gave rise to the idea of a third generation innovation model where focus interactions and couplings where innovation is seen as a sequential process that is divided into functionally distinct but interacting and interdependent stages (Kline & Rosenberg, 1986; Rothwell, 1994).

In and between firms there are continuous processes of feedback between design, product development, production, trial and error, and marketing. These processes interact with research. Firms perceive existing available knowledge and technology as an available pool where firms can tap in when searching for new solutions externally. The science and research community constantly adds new knowledge to this pool, which makes the contribution of science mostly indirect (Kline & Rosenberg, 1986). The model thus combines supply-push and demand-pull perspectives. Commenting on the linear models the authors conclude that science is essential to innovation, but it is often not the initiating step. Instead it is employed at all points along the central chain of innovation, as needed. In this sense the role of science, as noted by Nelson and Rosenberg (1993), can be seen as both a leader and a follower in modern economic systems (R. R. Nelson & Rosenberg, 1993).

One main conclusion from the increased research on innovation was that the explanations for success and failure in innovation were always multi-factoried – meaning that it was not about doing a few things right but rather a well-balanced mix between coordination, key individuals, entrepreneurial flair and ‘doing most tasks competently’ (Rothwell 1994). As complementary to the latter Dodgson reports that the increased innovation research efforts also identified enormous diversity in the processes underlying innovation – especially sectoral differences. A study of 84 important innovations (1974) concluded that “perhaps the highest level of generalization that is safe to make about technological innovation is that it must involve synthesis of some kind of need with some kind of technical possibility” (Dodgson et al., 2005). It is safe to conclude that the innovation process is both better understood and becoming increasingly complex with the third generation model which is further challenging for making general statements about the role of science and technology across innovations, regions and sectors.

2.2.4 4th generation – the integrated model
The traits of innovation processes that characterize the third generation model such as communication of information internally and externally, feedback loops and increasing complexity were only augmented in the following decade.

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 production organization. Also, 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. In general firms were becoming engaged in intensive external networking activities. Another central factor for how firms

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\(^1\) Rothwell refers to [Cooper, 1980; Hayvaert, 1973; Langrish et al., 1972; Myers and Marquis, 1969; Rothwell et al., 1974; Rothwell, 1976; Rubenstein et al., 1976; Schock, 1974; Szakasits, 1974; Utterback, 1975].
conducted themselves regarding innovation was the rise of Japan. During the 1980s it became clear that Japanese firms were superior in innovation, and ‘western’ firms started to look for inspiration in the Japanese product development system which was characterized by being able to simultaneously shorten product life cycles and production costs. According to Rothwell (1994) the performance of Japanese firms was based on their ability to in an early phase integrate firm-external actors (suppliers) in product development processes at the same time as they integrate intra-firm departments. The key difference from the third generation model is that here the stages of the innovation process are not seen as sequential (in series) but rather as \textit{mutually integrated} (in parallel). Such a model involves intensive communication of information and knowledge between actors in the innovation process – being internal or external. One advantage of this kind of interaction and mutual shaping of the end product was the creation of the ‘design for manufacturability’. This means that product development was organized around products designed to be manufactured at a relatively large scale. The consequences were that product development processes became faster, and that often unit costs were low. As a consequence of the changes in the business environment and the impact of the Japanese innovation mode the management and policy challenge of innovation became significantly more complex. The fourth generation model contain much 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). One implicit thesis of this model is that the better communication is, the more successful/efficient is the innovation process.

\subsection*{5\textsuperscript{th} generation – the systems integrations and network model}
Already when writing in 1994, Rothwell (1994) identified an emerging fifth generation model of innovation. Many of the important aspects of the fourth generation model continue to matter in the fifth, and with increasing intensity. Dodgson et al. (2005) observes a range of changing characteristics from the mid 1990s that are relevant for innovation processes. Firms now widely have innovation strategies, and they are better formulated and implemented than earlier. Firms also exhibit a greater appreciation of knowledge, creativity and learning as sources and outcomes of innovation. Also firms’ environment changes further in this period which includes: (a) expansion of (international) strategic integration and networking due to globalization of markets, sources of technology and partners; (b) a realization that value comes less from ownership and more from connectedness to relevant markets, knowledge and actors – for example in the connectedness of products and services in service solutions; (c) the level of technological integration is increasing via combinations and fusions of different knowledge bases.

In this context Rothwell (1994) sees the ability to control product development speed (time-to-market), manufacturability of products (production costs) and to have flexibility in product development activities as central parameters for performance. In the fourth generation model the latter was achieved via parallel integration and communication. These features were intensified in the fifth generation mainly by force of ICT systems that are able to speed up the innovation processes. Rothwell (1994) formulates this as “\textit{the technology of technological change is itself changing}” because ICT has the capacity to speed up parallel and integrated processes of innovation (via faster/better communication).
Figure 1: The systems integrations and network model

In summarizing his observations, Rothwell (1994) lists the following factors as significant in the fifth generation model: “centrally, integrated and parallel development processes, strong and early vertical linkages, devolved corporate structures and the use of electronics-based design and information systems... innovation has increasingly involved horizontal linkages such as collaborative precompetitive research, joint R&D ventures and R&D-based strategic alliances, i.e. innovation is becoming more of a networking process”. On this basis, Rothwell goes on to define contemporary (industrial) innovation as “process of know-how accumulation, or learning process, involving elements of internal and external learning”.

The observations that led to proposing a 5th generation innovation model reflect fundamental changes in the dynamics of capitalist market economies. It has been argued that the current phase of global capitalism can be characterized as a ‘knowledge economy’ because economically useful knowledge and technology are increasingly determinants of international competitiveness of firms and nation states. An extension, or precision, of the latter concept has been formulated by Lundvall and Johnson (1994) as the ‘learning economy’ (B.-Å. Lundvall & Johnson, 1994). The starting point of analysis is that if knowledge is the most important factor for economic performance, then learning must be the most important process. Their main point is that not only has knowledge become more important, but what is truly novel in this current phase of global capitalism is the speed with which economically useful knowledge changes. They define the learning economy as an economy where the ability to learn is crucial for the economic success of individuals, firms, regions and national economies. Learning refers to building new competences and establishing new skills, and not just getting access to information. A characteristic of the learning economy is that actors need to renew their competences more often than before (Lundvall and Johnson 2000). The rise of the learning economy is clearly observable in the fourth and fifth generation models where especially the speed up of innovation is characteristic.

The increasing complexity in the learning economy entails that innovation has moved from being an individual process (the inventor), to a corporate activity (firm R&D), and to what can be called ‘open innovation’ or ‘distributed innovation’ (Dodgson et al., 2005). The increased 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 (K. Foss & Foss, 2002). This gives the learning economy its network character. The concept of distributed innovation fits well with
the fifth generation model where firm-external knowledge and learning is increasing in importance. The firm-external factors concern mainly linkages to suppliers, Science and technology infrastructure, knowledge bases, partners and competitors, users, suppliers. The growing importance of firm-external linkages suggests a systems approach to understanding innovation. According to Smith (1999) system approaches to learning and innovation do not only focus on the performance of individual firms, but also on how they are embedded into complex social and economic relationships in their environments (Smith, 1999) – the latter points to an innovation system framework. One of the fundamental insights from the innovation system literature is that economic performance is systemic. The latter implies that the whole is more than the sum of its parts, and that the interrelationships and interactions between elements are as important for processes and outcomes as are the elements themselves (B.-Å. Lundvall, 2007). I will elaborate on the innovation-system approach in section 2.3.

2.2.6 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 naturally 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. The authors are hesitant with allocating time periods to the respective policy types but the shifts in policy rationale are reflected in the changing understanding of innovation (the generations) (B.-Å. Lundvall & Borrás, 2005). Moreover, as noted by Dodgson et al. (2005), just as the different generations of innovation coexist so do the different types of policy coexist. It is a cumulative rationale that grows increasingly broad as the process of innovation is better understood and becomes more complex.

(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. It is seen as capable of contributing, if not solving, problems with national security, health and economic growth. With this perspective the most relevant actors are universities, research institutions, technological institutes, and R&D laboratories. Considerations about how these entities were coupled to the rest of society existed but were generally in the background. One can therefore say that science policy concerns only a limited part of the innovation system which is more precisely described as a science and research system. (b) During the 1960s the rationale behind science policy evolved into technology policy. The main difference is that the emphasis on the links to industry is stronger. The objective changed from being about good or more science, to addressing economic and national objectives. The elements of the innovation system in focus remain universities, research institutions, technological institutes, and R&D laboratories. But the attention moves from universities toward engineering and from the internal organization of universities toward how they link to industry. Technology policy may go even further and include the commercialization of technologies even though that is closer to innovation policy. The shift clearly reflects a critique of the linear model in the form of an understanding that good science does not automatically generate innovation in firms. Even though it is not explicit, 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 actors as firms, policy concerned with business regulation, technology transfer and private R&D institutes.

(c) Lundvall and Borrás (2005) identify two versions of the innovation policy ideal type. (i) A lassiz-faire version where focus is on horizontal measures, framework conditions, intellectual property rights, basic
research and education as only legitimate forms of innovation policy. Other forms of policy is negatively labeled as 'picking the winners' which is seen as a waste of resources. The argument rests on a sort of market fundamentalism (Rodrik, 2006) where the predominance of the market and ‘free’ competition becomes the most important prerequisite for innovation, and where firms always know the optimal choice and acts accordingly. Such a perspective in principle recommends the same medicine to all types of innovation issues across contexts. Obviously, this tradition completely ignores the research on innovation described in previous sections. (ii) A systemic version which is derived from the concept of an innovation system. In this version innovation policy basically concerns all relevant aspects of society that (significantly) influences the process of innovation (5th generation model) which makes it a systemic policy tool. 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. One can say that the rationale for (i) is market failure while the rationale for (ii) is both market failure and system failure which refers to failures in e.g. institutions or couplings – factors that go beyond the market.

Lundvall and Borrás (2005) points to the declining growth rates in the 1970s as a major reason for innovation policy becoming broadly used as a concept. In the same period the research in innovation studies intensified with focus on the sources of innovation, productivity and international competitiveness. Thus, the innovation-system approach emerged in interaction with the coupling- and chain-link model (third generation) and subsequently with the fourth and fifth generations. The generations of models are in many ways the micro foundations for the innovation-system approach. The innovation system approach can be seen as a framework that brings together the most important results from four decades of innovation studies. It makes use of empirical material and analytical models developed in innovation research with a theoretical emphasis on institutional and evolutionary economics.

2.2.7 Conclusion
The conceptualization of innovation and the mapping of different generations of innovation models in this section have illustrated that contemporary innovation is best understood as a process characterized by being non-deterministic (uncertainty), non-autonomous (not science push), open and distributed, and thus inherently collective. The increasing openness and networking character and speed of innovation in the learning economy is one important reason why innovation must be understood as a systemic process. This feature implies that an innovation-system approach is a suitable theoretical framework for analyzing innovation activities. I will turn to this approach in the following sections.

The table below illustrates the generalized characteristics of the different generations of innovation models. Dodgson el al. (2005) argues that 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. The coexistence stems mainly from diversity in modes innovation across firms, industries, sectors, regions and nations (Dosi, 1988; Malerba, 2002).

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2 Jacobsson and Johnson (2000) identifies the following system failures: (i) poorly articulated demand, (ii) local search processes which miss opportunities elsewhere, (iii) too weak networks (hindering knowledge transfer), (iv) too strong networks (causing ‘lock in’, dominance of incumbent actors, no necessary creative destruction and new combinations), (v) legislation in favor of incumbent technologies, (vi) flaws in the capital market, (vii) lack of highly organized actors, meeting places and prime movers.
The table also links the generations of innovation model with the different types of innovation policy. It is obvious that the concept of innovation broadens as the understanding of its nature increases. In this sense the 5th generation model contains all the other generations but they would constitute special cases of the 5th generation because they are ‘narrower’. Likewise, innovation policy can and should incorporate science policy and technology policy. The diversity in innovation dynamics across contexts and time imply that innovation policy must be designed according to context. 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 superior to prior models.

2.3 Innovation System approach
In order to properly bridge the insights obtained in the previous section with the innovation-system approach, I will present a brief story of the evolution of innovation policy in the Netherlands. This practical example taken from Smits (2004) exquisitely combines a practical example with abstract theoretical understandings of innovation, see text box.

### Evolution of innovation policy in the Netherlands

Smits (2004) reports on the evolution of innovation policy in the Netherlands as an illustration of how the shifts in generations of innovation models and policy implications are related. It also illustrates why a systemic approach is needed. In the Netherlands the first attempts at making innovation policy were motivated by the economic crises in the
1970s and the wish to generate international competitiveness and value added. At the time the country did not have any type of innovation policy. The first attempts were strongly supply-orientated and dominated by financial instruments to stimulate R&D. The initiative did not have much success because R&D results were not diffused broadly and incorporated by firms which severely hampered impact on competitiveness and the economy (science policy). The solution proposed to this situation was to strengthen interaction between science and industry. This was implemented during the 1980s by inter alia stimulating the mobility of researchers from academia to private enterprise and by establishing a network of regional innovation centers (technology policy).

Smits (2004) notes that even though the innovation centers clearly improved the diffusion and use of new technologies there was in the 1990s still a significant mismatch between the needs of firms and the knowledge produced in the research system. Policy had to look beyond production and diffusion of knowledge, and consider the role of the users of knowledge. This inspired a user-oriented approach to innovation policy where focus increasingly was on interfaces between users and producers of knowledge. This also entailed a focus on the ability of the individual firm to absorb new knowledge produced elsewhere and transform it into innovation via processes of learning. One result was increased emphasis on supportive infrastructure such as distributed knowledge bases, risk capital schemes and ICT infrastructure. The focal point of analysis was at this point the individual organization or bilateral relations between organizations. Still, the lessons in the 1990s showed that many actors were actually involved in the process of innovation in relation to finance, knowledge, marketing, education, interaction between users and producers of knowledge. On this account researchers started to view innovation as a systemic phenomenon (Smits & Kuhlmann, 2004).

On the basis of the Dutch experience it is possible to identify two broad development trends: (i) there is a move from exclusively focusing on the supply of knowledge (science policy) to gradually seeing the demand for knowledge from industry as important (technology policy), and to focus on the interactions between supply and demand in a systems approach (innovation policy); (ii) simultaneously there has been a shift in unit of analysis from looking at one or few individual organizations to increasingly understanding firm innovation as a context-dependent process by looking first at clusters, and eventually moving to a system level for grasping the process.

The core topic of IS research is to understand the impact of technological change (in the broadest sense) on economic performance (growth and development), which often takes place via international competitiveness. In order to understand the mechanisms involved in the latter, the innovation system approach emphasises the interdependence between technical and institutional change as the central theoretical area (Freeman 2003). The latter refers to whether an institutional set-up is characterised as enabling, obstructive or indifferent towards innovation. According to Lundvall (2007) the term first appeared as a national system of innovation (NIS) in an unpublished OECD paper from 1982 written by Chris Freeman. The paper was about how countries can build knowledge and knowledge infrastructure at the national level with the aim to promote economic development and international competitiveness. This was a first, and still strong standing, point, but further elaborations have given more specificities and substance to the term without losing its core intention. The focus on institutions is important because it draws attention to patterns of interaction and to that such patterns are diverse across economic systems.

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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 and Johnson 1997). A main point is that institutions provide an incentive structure for human behaviour, which in turn will determine the attainable economic outcome in a given context (Sokoloff and 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 behaviour 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.
Lundvall, Vang et al. (2009) gives an overview of a range of definitions of IS put forward over the years – they are slightly diverse but complementary, see text box in appendix. It is obvious from these definitions that especially institutions, organisations and their interactions are the main factors that determine the IS. I will here stick to the broad and basic definition of an innovation system given by Lundvall (1992a, p. 2), which is: “the elements and relationships which interact in the production, diffusion and use of new, and economically useful knowledge”. He further stresses 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.

2.3.1 The broad and narrow approach
As mentioned above the IS approach has, almost from the beginning, encompassed two different perspectives, a narrow one primarily linking innovation directly to science and a broader one encompassing learning, innovation and competence building in the whole economy (Lundvall 2007).

The narrow innovation system approach aims at mapping indicators of national specialisation and performance with respect to innovation, R&D and science and technology organisations. In contrast, the broader approach aims at taking into account social institutions, macroeconomic regulation, financial systems, education and communication infrastructures and market conditions as far as these have impact on learning and competence building processes (Lundvall, Vang et al. 2009). The broad approach has mainly been developed on the basis of the experiences of small, open economies (Scandinavian countries). Small economies have a handicap in the ‘high-tech’ industries simply because they have fewer resources to invest in R&D. Thus, the presence of or number of areas characterized by strong R&D capability, is likely to be smaller in small economies. Partly as consequence of this, the diffusion of innovation and absorption of external innovations have been more important for their economic welfare than development of ‘science-based’ (radical) innovations. The mechanisms of diffusion and absorption makes the IS approach broader, because it now involves the whole population of firms, and not just the firms excelling in patents and R&D expenditure. These insights do not imply that processes of diffusion and absorption are not important in large economies with strong R&D systems, or that R&D is not important for smaller countries.

The differences in approaches are further manifested in the definition of innovation used and thus the sources of innovation included. The narrow approach defines innovation as products or processes new to the world introduced in the market place, while in the broad approach innovation is seen as a process where equal emphasis is given to processes of production, diffusion and use of new knowledge (Johnson, Edquist et al. 2003). The narrow approach tend to see science and R&D as main sources of innovation while in the broad approach innovation is mainly seen as emanating from processes of interactive learning across the whole economy. In the optic of an interactive learning approach to economics the difference between a broad and narrow approach is basically about which types of linkages that are seen as important. In the narrow one it is mainly linkages between science and firms, while linkages between users and producers in production are seen as less important and basically concern the process of diffusion, which is explicitly separated from the narrow definition of innovation. An additional aspect of this debate is that it is not obvious that narrow, ‘science-based’ innovation is more important for development than innovation in a broad sense, and therefore adhering to the narrow approach can result in misleading policy conclusions (Johnson, Edquist et

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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.
al. 2003; Lundvall 2007). ‘Science systems’ are an important factor, but most countries are 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). Moreover, taking a narrow innovation system approach tends to exclude the role of demand from the majority of industries in any country.

2.3.2 Different levels (and boundaries)

Following the initial work on NIS, IS analysis developed in different directions. Several researchers did not find the national level appropriate for understanding certain aspects of innovation and economic performance; therefore other versions of the IS approach have been developed. Among these the most important are the regional IS (RIS) (Asheim and Gertler 2005), the sectoral IS (SSI) (Malerba 2002; Malerba 2005) and the technological IS (TIS) (Carlsson and Stankiewitz 1995). Within these approaches the distinction between narrow and broad IS persists. The different approaches reflect that an IS may be delimited (i) spatially, (ii) sectorally or (iii) according to technology/knowledge base (the breadth of activities they consider). These determinants of limits may be applied in a mix as well. They may all be fruitful given the object of the research and in general the approaches complement rather than exclude each other, see figure in appendix. 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 et al. 1997). The latter implies that a given innovation system is embedded in a broader social system, and that system delimitations ought to be decided by research objective.

2.3.2.1 Sector level

The most prominent argument for focusing on the sectoral level of innovation systems is that innovation dynamics differ significantly across sectors (Dosi, 1988) which therefore also makes it relevant to focus on sector levels to make foresights useful and meaningful (Weber 2010).

Innovation dynamics differ across industries because: (i) they dependent on different knowledge bases, and the technological opportunities differ across knowledge bases as a consequence of existing (national) strongholds and firm capabilities, and of types of knowledge (learning opportunities); (ii) technological and innovation competences, embodied in people and firms, are unequally distributed across sectors as a consequence of specialization of industrial structure and of education system (learning capabilities); (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 are also likely to differ. These differences on sector level have to some extent been mapped by Pavitt (1984), and Nelson (1993) shows how innovation dynamics differ across countries (partly as result of diverse industry structures). These insights generate an argument saying that innovation is a context-dependent phenomenon, and that I therefore should avoid unnecessary aggregations and generalizations. Since my concern is the move from firm to sector, a sector innovation system (SSI) is the most suitable version of the innovation-system approach in this situation.

2.3.3 A theoretical core

The innovation system approach may be seen as bringing together the most important stylized facts about innovation. It makes use of empirical material and analytical models developed in innovation research, as well as in institutional and evolutionary economics (Lundvall and Borrás 2005). Still, it covers several different but mainly complementary lines of research, but despite this diversity a basic theoretical core can be identified. According to Johnson, Edquist et al. (2003) the central building block is evolutionary
economics and the derived ontological consequences: (i) one implication is the absence of equilibrium assumptions. An economic system never fully reaches equilibrium; it is always characterized by disequilibria, change and ‘structural tensions’ – dynamics first; (ii) it is assumed that social systems evolve over time in a path-dependent manner which is characterized by positive and negative feedback mechanisms; (iii) the emphasis on path dependency is combined with a view on the individual as subject to ‘bounded rationality’ and limited information-processing capacity, which makes choices and search local rather than global; (iv) the latter implies that innovation follows certain, and different, trajectories across time and space; (v) this implies that one expects 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: (vi) that knowledge is different from information, and that parts of knowledge are tacit and others are localized (result of path-dependent learning); (vii) knowledge and information are shared and flow in relationships between actors; (viii) knowledge is a result of learning, and learning is predominantly interactive; (ix) knowledge and learning are inputs to innovation, which is a fundamental factor in economic development. A process which is seen as endogenous; (x) holistic and interdisciplinary approach; (xi) innovation is a non-linear process.

2.3.4 Centrality of Interactions – interactive learning

A pivotal proposition in the IS literature is that the most central and important activity in an IS is learning and that learning is mainly interactive. One can distinguish between different types of learning. Johnson (1992) distinguishes between: (i) isolated imprinting, (ii) rote learning (repetition), (iii) learning by feedback (another person tells you his opinion), (iv) systematic and organised search for new knowledge. These forms of learning have increasing levels of interaction. Noteboom (2000) argues that as competition and specialisation, and in turn complexity increase, the value of firm-external knowledge increases, which makes interactive learning the most important type of learning for innovation and development in the learning economy.

The idea of interactive learning was first introduced to the innovation studies environment in the form of user-producer interaction (B.-Å. Lundvall, 1985). The starting point for Lundvall's analysis is that users and producers are formally independent entities separated by a market, but related through durable linkages wherein transactions and communication take place. Innovation is seen as a cumulative process and as emerging 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. Thus, in order to generate the best-possible product for the user, the producer needs detailed information about bottlenecks in production. Also, the more information users have about technological opportunities, the better they are at formulating their needs. This situation entails interdependence in innovation endeavours between users and producers via interactive learning.

The user-producer approach has several implications for the understanding of innovation, structural change and economic development: (i) the interdependence between firms interacting in a given institutional context implies that innovative and economic performance changes from being exclusively individual to being systemic; (ii) the approach suggests that innovative activities will be strongly related to prevailing economic structure because it sees existing bottlenecks as motivation for learning; (iii) communication skills and ability to identify problems and possibilities on behalf of both users and producers become very important; (iv) the information needed in interactive learning cannot be communicated via price signals in a market – it
requires different kinds of qualitative, sometimes personal, interaction extended over time. It thus makes sense to distinguish between linkages, which only channel arms-length monetary transactions and linkages that channel qualitative information. Hence, terms like the quantity of linkages and the quality of linkages are useful. On a more aggregated level Lundvall (1985) and Fagerberg, Mowery et al. (2009) argue that the quantity and especially the quality of linkages between firms in an economy are likely to improve the ‘efficiency’ of innovation activities. This refers to that with detailed information about problems and potential solutions, it is more likely that ‘satisfactory’ innovations will be generated. Interactive learning between users and producers is a fundamental part of the micro foundations for the innovation-system approach.

Due to the centrality and nature of interactive learning in the performance of an innovation system, interactions and relations between organizations should be central to any policy suggestion (C. Edquist, 2001). It should though, focus both on the organizations in the system and on the relations between them (Charles Edquist & Chaminade, 2006). As innovation is most often a recombination of existing pieces of knowledge (Utterback 1994; Ahuja and Katil 2004), building new linkages/interactions between existing organizations is equivalent to stimulating innovation in the system. The focus on interactions also implies that avoiding system lock-in situations is as important as creating new ones. A key consequence of understanding innovation as an interactive and systemic process is that the competence of users of knowledge (demand) is as important as the competence of producers of knowledge (supply).

2.3.5 Policy rationale from Innovation Systems

In the innovation-system approach, innovation (change) is understood as an open-ended and irreversible process which implies that actors will most often be in a situation that is not completely familiar to them – thus, characterized by uncertainty (different from risk). Actors follow habits, rules of thumb and routines to manage uncertainty (Nelson 1995). The latter renders ‘optimality’ in an IS meaningless. The absence of optimality implies that comparison with ‘perfect states’ of systems with real systems is not an option (this is the core of the ‘market failure’ approach). Instead a system failure approach is needed. A system failure can be conceptualized as a ‘problem’ in the system, and problems are best identified by comparing with other systems (Charles Edquist & Chaminade, 2006).

In order to be able to address a system failure one must understand the causal mechanism underlying it (how, why and when did this situation emerge?), which often requires deep and detailed knowledge about the concrete IS at hand. The latter approach is similar to what Rodrik (2006; 2009) has presented as a ‘diagnostic approach’ to economic development. Transferred to an IS context his basic points are that (i) barriers to learning and innovation must be diagnosed in the concrete situation; (ii) policy initiatives should be made to find specific solutions via experimentation and learning; (iii) once barriers are gone, institutions to sustain learning and innovation should be built. Given that there are no simple paths to economic growth and development, and that any path necessarily is unclear ex ante, experimentation with policy and institutions is the only possible strategy. Policy learning, which is to be able to systematically experiment and learn from experience (Kemp & Weehuizen, 2005), is therefore an immensely important part of policy and strategy making in the IS approach.

2.3.6 A forward-looking dimension?

The argumentation above is well-known, but it is inclined to unfold as a need-driven diagnosis instrument, which tends to be ‘backward looking’ and to ignore future opportunities. The latter point has also been
formulated as a critique of the IS approach. It has been accused of giving too much emphasis to structural and historical elements and to the randomness in the development of existing IS because this leaves only little advice on how to build or transform systems (Bergek, Hekkert, & Jacobsson, 2008). A more explicit forward-looking dimension is missing in the innovation-system approach.

Still, several IS scholars suggest that thinking about the future and its potential challenges is relevant for the working of an IS. For example: “It is important to note that problems motivating public intervention might concern the future. In fact, the ‘problem’ might not yet have emerged, and a policy addressing this type of situation might be called an opportunity-creating or anticipatory policy” (Charles Edquist & Chaminade, 2006). Still, there is no explanation of how such a forward-looking dimension could be developed and understood.

One can argue that a sensible place to introduce an explicit notion of the future into the innovation-system framework would be its core (micro foundations) of interactive learning. The interaction between users and producers requires a shared understanding of the future with respect to expectations and the desired direction/outcome of the interactive learning process – in fact it is crucial for meaningful communication. This dimension ought to be made explicit at all levels of user-producer interaction – especially with respect to public policy (normativeness/values).

The absence of an explicit notion of the future implies that the innovation-system approach have problems in addressing normative visions for the future (desirable futures) such as how to achieve a low-carbon economy which concerns the direction of innovation. The vision of the future will in any moment in time guide the direction of interactive learning because our image of the future is used to evaluate what is rational and what isn’t. It therefore seems meaningful to try to develop tools to think explicitly and systematically about the future and about normativeness/direction of innovation within the innovation-system framework. The work of Frank Geels can be seen as a step in this direction (Geels, 2004). It is my proposition that foresight has the potential to contribute in developing a forward-looking dimension in the innovation-system framework. This issue will not be pursued further in this paper, though.

2.4 Conclusion

The above presented a literature review of the evolution in and developments of innovation studies, and presented the innovation-system approach as the latest stage of research on and understanding of innovation in the learning economy. The latter addresses the research question “What is the innovation-system approach?”

The next section will give a review of foresight and illustrate the linkages to innovation studies over time. Subsequently I will elaborate on the consequences for foresight of accepting the innovation-system framework as its theoretical foundation and thus main rationale. An important lesson we should take with is the notion of diversity. Diversity implies that innovation modes and processes differ greatly across firms, sectors, regions and nations. This implies that in order to be meaningful any attempt to develop a forward-looking dimension would have to take into account the concrete innovation dynamics of the system under consideration. If this isn’t done one would impose the same innovation model on all innovation processes, which is equivalent to violation of the accumulated knowledge about innovation presented above, and the exercise would be deemed to fail.
3 Foresight: What, why and how?

In the learning economy social and economic change has sped up over recent decades inter alia due to an increasing globalization which involves fast diffusion of communication, culture, transport, trade and finance. The world has become more complex and uncertainty is by most experienced as increasing. In that context governments, universities and firms must make decisions about investments in knowledge production which despite heavily intensified competition, increasingly is seen as the main driver of economic prosperity. 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 (Luke Georghiou, 2001). In this context no country is big enough to avoid prioritization of resources in S&T (Martin, 1995). Therefore the number of foresights increased through the 1980s, exploded in the 1990s and continues to grow in popularity in the 2000s (Butter, Brandes, Keenan, & Popper, 2008). Foresight can be understood as formulating a forward-looking strategy for innovation on the basis of ‘what is’ (exists) and on a qualified judgment of ‘what will be’ (will exist).

The purpose of foresight is not to predict the future but to imagine multiple futures and their consequences, and on that basis engage in informed decision-making. Such an exercise will involve trends that are relatively large, long-term and predictable such as global population growth, demographic change, migration patterns, China and India’s economic growth, climate change and the increasing global use of natural resources. Most trends though are very context-dependent, unpredictable and fast – examples are new technologies, oil crises in 1970s or the democratic uprisings in the North Africa 2011. Foresight thus rests on two key assumptions: (i) that the future is not laid out, that multiple futures exist; (ii) and that decisions and actions taken today can affect the future. The latter point implies that to implement decisions, it is necessary to involve key stakeholders in the process because these will be the actual means of change.

In this work is inspired by a working definition of the European commission where foresight covers the activities (a) to think the future, (b) to debate the future and (c) to shape the future (European Commission, 2002). It is thus not a tool for predicting the future, but a process aiming to develop shared problem perceptions, make differences in expectations explicit and identify needs (and options) for action. (a) Thinking the future (the cognitive dimension of foresight): foresight exercises try to identify new trends and trend breaks to guide decision-making. Foresight activities aim at identifying today's innovation priorities on the basis of scenarios of future developments in science, technology, economy and society. (b) Debating the future (the value based dimension of foresight): foresight as a participative process involves different stakeholders (e.g. industry, public authorities, research organizations, industry representatives, NGOs) and its activities can be organized at different levels like cross-national, national, sectoral or regional. The aim is to organize open discussion between the participants in order to create a shared understanding. (c) Shaping the future (pragmatic and implementation-oriented dimension of foresight): foresight aims at identifying possible futures and future developments, imagining desirable futures, and identifying strategies that facilitate implementation. Foresight results are generally fed into public decision-making, but they also support participants to develop or adjust their strategy. Thinking, debating and shaping the future of different but interlinked sectors is crucial today because innovation is a collectively shaped process, a distributed process, and a path dependent process (Weber 2010). Thinking, debating and shaping the future of for example sectoral innovation systems has to take into consideration the context-dependent innovation dynamics of the sector in question.
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 obvious that ‘correct/optimal’ decisions cannot be made in foresight but the age I are living in demands that investment decisions and priorities are made under strong uncertainty – it is thus similar to the ‘theorem of the second best’ in economics: just because it is not ‘optimal’ we cannot ignore the challenges. Finally, it is important to stress that the goal of and motivation for doing foresight is to stimulate innovation that generates international competitiveness, economic growth and improvements in citizens’ quality of life (in public policy perspective).

What foresight is has changed over time (what). These changes have been motivated by changing rationales for actually doing foresight (why) that in turn were inspired by internal and external lessons emerging from other fields of research and in society at large. This involved the methods applied and the way a foresight exercise is designed (how). TheseWhats, Whys and Hows have over time coevolved and made it possible to identify different generations of foresight. These will be presented in the following. The latter also implies identifying the most recent trends within foresight research since these can be seen as arms stretched out towards the innovation-system approach. Before engaging in the identification of the generations it is helpful to uncover the roots of foresight because these are explanatory factors behind the changes in foresight understanding and practice.

3.1 Roots of foresight

(1) According to Martin (2010) 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. 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 (Martin 2010).

(2) According to Miles (2010) foresight is also rooted in a European tradition of futures studies 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.

The roots of foresight outline some basic distinctions in the research area. One major dividing line is between forecast and foresight that clearly are inspired by very different scientific paradigms, see table.

<table>
<thead>
<tr>
<th>Forecast</th>
<th>Foresight</th>
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<tr>
<td>Goal</td>
<td>Prediction</td>
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<tr>
<td>Performance</td>
<td>accuracy</td>
</tr>
<tr>
<td>Description</td>
<td>Set of techniques with single outcome</td>
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<td>Output</td>
<td>Accurate/correct/efficient decisions</td>
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<tr>
<td>Ontology</td>
<td>Positivism, rational choice</td>
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<tr>
<td>Understanding of the future</td>
<td>The underlying assumption of predicting the future is that only one probable future exists, and that this can be linked in a uni-linear and deterministic way to the present and the past</td>
</tr>
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Table 1: Forecast and foresight

From its conception the nature of foresight has changed markedly over the years in a process that is characterized by ‘internal’ struggles and external inspirations. The internal struggles consist of varying dominance of its different roots. The diversity of understandings of foresight is growing it is inter alia seen as, or as a tool for: systematic analysis, long-term vision, national strategic planning, science and technology policy making, obtaining long-term needs, prioritization and allocation of resources, science and technology decision-making and taking actions (Yuan, Hsieh, & Chang, 2010). The external inspiration comes from other parts of social science with innovation studies being among the most dominant ones. 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.

3.2 Generations of foresight

Foresight is a concept that has several diverse definitions across scientific communities (It is used in disciplines as medicine, sociology, business studies and psychology. Despite the diversity it is possible to identify the contours of some patterns. With a focus on national foresights Miles, Harper, Georghiou, Keenan, and Popper (2008) have identified broad changes in the understanding and practice of foresight since its birth until the present. These changes are predominantly motivated by the changes in the underlying rationale for doing foresight (why). On this basis they identify the contours of five generations of foresight over time.

The essential rationale 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. According to Martin and Johnston (1999) foresight is thus about improving the efficiency of investments in innovation; of innovation policy. It is thus understood as an instrument for innovation policy (one of several). The specific rationales for foresight have changed as (in co-evolution with) the understanding of the causalities between science, technology, innovation and economic development has changed, and as the world has changed. Sources of change can thus be divided into (i) knowledge about innovation dynamics, and (ii) the changes in innovation dynamics; cf. previous chapter.

### 3.2.1 1st generation

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 (Luke Georgiou, 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. For example that it is possible to know exactly which innovations would be needed or most efficient in the future. It can be argued that the core rationale for this type of innovation policy (just as for the linear model of innovation) is to correct the market failure generated by the fact that knowledge is a public good (Arrow, 1962). The rationale behind the 1st generation was gradually undermined by the critique of the science-push model of and the fact that forecasting was partly discredited due to its failure in predicting the crises of the 1970s. This rationale is equivalent to that behind science policy.

### 3.2.2 2nd generation

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. It has a strong emphasis on matching technological opportunities with market and nonmarket (environment and social issues) developments. Representatives from industry are now included among the key actors along with scientists, and actors who are able to bridge the gap between them. One can argue that the changes from the 1st generation to the 2nd were inspired by the progress made in innovation studies conceptualized as the demand-pull model and parts of the chain-linked model of innovation. It was often structured in terms of industrial sectors to better accommodate the demands from firms. The latter reflects the move towards technology policy. The rationale can be characterized as a more ‘advanced’ market failure. Focus is on correcting for asymmetric information, ‘strong’ uncertainty (not risk) or firms’ inability to appropriate benefits (Luke Georgiou, 2001; Miles et al., 2008).

### 3.2.3 3rd generation

The 3rd generation model is characterized by a ‘broadening’ of foresight and by shifting (adding) the main rationale from market failure to system failure. It was first formulated by Irvine and Martin in (1984) as (modern) foresight, and was motivated by developments in Japan. There foresight wasn’t about forecast but rather about thinking, debating and shaping the future through large and broad participatory workshops. This foresight practice seemed to contribute the country’s technological and economic success by being a more ‘efficient’ (than EU practice) innovation policy. Especially the use of bottom-up inputs and process benefits were noted (Martin, 1995; Miles, 2010). The latter was partly inspired by developments in innovation studies in the form of the development of the chain-link model and subsequently the Japanese-inspired integrated model of innovation (Miles highlights his inspiration from the SPRU environment in the 1980s where the innovation-system framework was being conceived) (Miles, 2010).
The insights from innovation studies that innovation must be understood as a series of integrated, interactive and parallel processes that requires extensive communication and is situated in a specific context, implied that foresight started to take onboard a more complex and non-linear view of innovation and its relations to its context. In the recognition that there were insufficient ‘bridging organizations’ in the socio-economic system foresight was seen as an arena for making the necessary network connections (Miles et al., 2008). The latter was the first recognition of a system rationale and it 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 (Luke Georghiou, 2001).

The 3rd generation model was formulated in the mid 1980s and gradually evolved throughout the 1990s in accordance with developments in related future-oriented disciplines and of innovation studies. In 1999 the innovation-system approach rationale was explicitly linked to foresight as a tool for ‘wiring up’ innovation systems. Martin and Johnston (1999) argued “central to the concept of the national innovation system is the vital importance of the interactions between the actors making up the system. To strengthen the national innovation system, I need to stimulate, extend, and deepen those interactions if the system is to learn and innovate more effectively. (Technology) Foresight offers a fruitful mechanism to help achieve this (p. 53).” This conceptualization of foresight as a systemic innovation policy/tool is mainly based on the process benefits of foresight. These were initially formulated as the 5 Cs: (1) Foresight enhances Communication (among companies and among researchers and between researchers, users, and funders); (2) Foresight contributes with a greater Concentration on the longer-term future; (3) Foresight can provide a means of Coordination (again among researchers and between researchers, users, and funders); (4) Foresight can help create a level of Consensus on desirable futures; (5) Foresight can generate Commitment to turning the ideas emerging from the foresight program into action (Martin & Johnston, 1999).

The use of the innovation-system rationale for foresight also implies (or vice versa) that foresight is seen mainly as a process rather than a product (report on policy recommendations and priority lists). This change from product to process gradually took place during the 1980s and 1990s as the system failure rationale took form (Cariola & Rolfo, 2004). The latter reflect the gradual move from technology policy towards innovation policy. It was especially promoted in foresights in the Netherlands where the capability building (learning approach) in the participating actors (visions, information, networking, inspiration) was highlighted as more important than “deterministic forecasts and blueprints” (Miles, 2010). Still, it is worth remembering that foresight rests on market failure and system failure rationales, and that both process and product outcomes can be beneficial (prioritizations still needed). The changes in foresight rationale are thus cumulative (Miles et al., 2008).

3.2.4 4th and 5th generation
Miles et al. (2008) have further identified a 4th and a 5th generation of foresight that both reflect a ‘broadening’ of the uses of foresight and hence also the diversity in designs; something that has unfolded mainly in the 2000s. The 4th generation is demarcated by seeing foresight as distributed. This implies that more stakeholders are identified as relevant participants, which increases diversity of participants. Also, most participants in foresight now have a desire to get something from it rather than merely serving the ‘funder/owner/sponsor’ (a process output). The 5th generation is characterized by a diversity of foresights
(designs) that are concerned with (i) different structures or actors within an innovation system, and (ii) the science and technology dimension of broader social or economic issues. Due to the complexity of these issues experts have a prominent role but are complemented by a broad range of actors. The increasing conceptual broadening and diversity of foresights reflects experimentation and application of diverse rationales as foundation for foresight. One can interpret these changes as that the results from innovation studies is entering the foresight discipline, and that the broadening/opening up of foresight reflects that insight that science and technology policy can’t function without the innovation-policy dimension. Butter et al. (2008) argues that current foresight practice has gone well beyond what is conceptualized as technology foresight (policy). In general the five generations of foresight models should be understood as ideal types (just as in innovation models) that probably do not exist in pure form in reality. Still, they reflect a trajectory of development within foresight. This is due to both (i) a change of innovation dynamics and (ii) an improved understanding of the process of innovation.

A contemporary suggestion for the main rationales for foresight is given by Barré and Keenan who summarize them in the five points; see table below (R. Barré & Keenan, 2008). A foresight can have one or several of these objectives. There is a broad consensus in the literature about these rationales. This reflects that, as explained earlier, rationales have changed cumulatively over time. It also reflects a diversity of theoretical foundations, or the lack of it, across foresight exercises.

<table>
<thead>
<tr>
<th>1.</th>
<th>Exploring future opportunities so as to set priorities for investment in science and innovation activities.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.</td>
<td>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 system does not match the needs of the country.</td>
</tr>
<tr>
<td>3.</td>
<td>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.</td>
</tr>
<tr>
<td>4.</td>
<td>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 such as youth.</td>
</tr>
<tr>
<td>5.</td>
<td>Building new networks and linkages across fields, sectors and markets or around problems. A different type of reorientation is sought when foresight is explicitly aimed at creating new networks and or clusters which break out of long-standing disciplinary or sectoral ties.</td>
</tr>
</tbody>
</table>

**Table 2: Rationales for Foresight 5th generation**

### 3.3 Innovation foresight?

Above I have presented a historical review of the evolution of foresight, and indicated that it has been inspired by results achieved in innovation studies. More recently it seems that parts of the foresight practice/academic field have adopted the innovation-system approach as its main rationale. This connection between the two fields has been noted by several researchers (R. Barré & Keenan, 2008; Cariola & Rolfo, 2004; Martin & Johnston, 1999; Smits, Merkerk, Guston, & Sarewitz, 2010) but despite obvious overlaps between them, innovation-system approach and foresight researchers in these environments hardly ever refer to each others’ work⁵ (Smits, Merkerk, et al., 2010). This suggests an unexplored potential for improving one, if not both areas. Actually, it has been suggested that foresight, which has always found and renewed its

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⁵ In the paper the authors discuss technology assessments and not foresight explicitly. Technology assessment is also a term with many definitions. These authors define as something nearly identical to foresight, as defined in this work.
rationales in social science (emphasizing economics of knowledge), is currently lacking behind the developments ongoing there (innovation systems), and that this calls for an update (R. Barré & Keenan, 2008).

Furthermore, several of the most recent trends in foresight practice and theory are bringing foresight closer to the field of innovation systems analysis. (i) Due to increased demand/pressure for strategic solutions in the learning economy, and the scarcity of forward-oriented approaches, foresight has been forced to increasingly point to solutions for existing problems than to identify 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 et al., 2008). Using the innovation-system framework as foundation can give foresight tools for addressing such issues systematically and maintain focus on innovation.

(ii) It is increasingly recognized that foresight is highly context dependent; that context parameters influences both the process and its potential impact on innovation activity (R. Barré, 2002; Cariola & Rolfo, 2004). This has given rise to a range of different designs e.g. regional and sectoral foresight. Likewise, innovation studies have shown that the process of innovation and its dynamics differ markedly across firms, sectors, regions and nations (Dosi, 1988). This implies that foresight must take this diversity into account in order to say anything sensible about innovation. The contextual nature of innovation is being recognized but actual work on this issue is largely absent (Schoen et al., 2011). That innovation is localized both geographically, culturally and cognitively is a main insight from the innovation systems research. Foresight can learn many lessons from the large number of diverse and detail-rich studies of innovation systems; this is another area for common ground.

(iii) There is an increasing focus on the demand-side in innovation policy in Europe which has implications for foresight. Foresight should increasingly move from being about priority setting towards being more focused on implementing insights and realizing structural change (Edler & Georghiou, 2007). The critique of the lacking 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 (Luke Georghiou & Cassingena Harper, 2011) and improve efficiency of innovation (via communication). The increased emphasis on demand, is perfectly suitable for the innovation-system approach which sees interactive learning as the most central process in economic development (B. A. Lundvall, 1992).

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. The comments and observations made above are strong arguments for linking foresight to the innovation-system framework as its theoretical foundation. In order to approach such a connection, and in order to establish some kind of order in the jungle, I propose the term Innovation Foresight to describe foresight that is explicitly founded in the innovation-system framework. Porter (2010) describes foresight concerned with innovation as different from science foresight or technology foresight: “it demands more attention to socio-economic contextual forces interacting with emerging technical capabilities to affect commercial product and services” (Porter, 2010). This implies that we can make interrelated distinctions between science, technology and innovation policy; between science, technology and innovation foresight; between 5 models of
innovation; and between 5 models of foresight. On overview of these inter-linkages can be seen in the table below.

Obvious implications of accepting the notion of innovation foresight are to pay more attention to the demand-side in innovation processes, and to integrate innovation-system analysis as a central piece in the preparation and design of foresights. A major implication concerns how we understand the currently-sued rationales for foresight; see table above. From the perspective of innovation foresight it is possible to establish a hierarchy between the rationales mentioned above, and eventually establish channels of causality between them. The most crucial objective of innovation foresight is to ‘strengthen’ the innovation system which involves building, transforming and 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. The latter is the main rationale for innovation foresight and it is the main motivation for doing foresight per definition. These causalities can be illustrated as in the figure below.

Given that the above argument is accepted it is meaningful to follow the innovation system literature and propose a distinction between ‘broad’ and ‘narrow’ version of innovation foresight (B.-Å. Lundvall, 2007). In the innovation-system literature the narrow approach tend to see science and R&D as main sources of innovation and pay most attention to the science system and a few high-tech industries, but not the innovation system as a whole. This would be equivalent to being concerned with science foresight and technology foresight which in some sense reflects another version of the linear model of innovation (B.-Å. Lundvall, Joseph, Chaminade, & Vang, 2009). The broad version has a broader approach to innovation and sees it as arising from interactive learning and competence building across the whole economy with firms as main protagonists. The science system (narrow) is seen as part of the innovation system (broad) but not delimited to it because innovation takes place in all sectors.
<table>
<thead>
<tr>
<th>Description of generations</th>
<th>Rational – theoretical underpinnings</th>
<th>Type of innovation policy</th>
<th>Structure/design</th>
<th>Label</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>mainly forecasting</td>
<td>The linear model of innovation</td>
<td>Science policy</td>
<td>Mainly expert group driven. elitist</td>
</tr>
<tr>
<td>2</td>
<td>Emphasizes matching of technological opportunities with market and nonmarket (environment and social issues).</td>
<td>The linear model of innovation. The demand-pull and chain-linked model</td>
<td>Science policy Technology policy</td>
<td>Increasingly involving firms and policy makers</td>
</tr>
<tr>
<td>3</td>
<td>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.</td>
<td>The linear model of innovation. The demand-pull and chain-linked model The integrated model of innovation</td>
<td>Science policy Technology policy Innovation policy</td>
<td>Increasingly involving socio-economic actors, more inter-disciplinarily</td>
</tr>
<tr>
<td>4</td>
<td>Foresight becomes distributed and broadened in scope. Intensifies characteristics of 3rd generation.</td>
<td>The linear model of innovation. The demand-pull and chain-linked model The integrated model of innovation Seeing innovation as open and distributed – the systems and networking model</td>
<td>Science policy Technology policy Innovation policy</td>
<td>Increasing diversity in terms of actors, levels, goals and designs</td>
</tr>
<tr>
<td>5</td>
<td>Foresight becomes more concerned with science and technology systems perspective and (or because of) increasing orientation towards solving societal challenges (grand challenges)</td>
<td>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</td>
<td>Science policy Technology policy Innovation policy</td>
<td>Increasing diversity in terms of actors, levels, goals and designs</td>
</tr>
<tr>
<td>Proposal: Focus on demand for knowledge, user-producer interaction, and innovation activities in firms</td>
<td>Innovation-system approach</td>
<td>Innovation policy</td>
<td>System delimitation and nature structures design.</td>
<td>Innovation foresight</td>
</tr>
</tbody>
</table>

Table 3: Conceptual linkages
‘Science systems’ are very important, but most countries are weak in this respect, and there is not always a clear cut relation between e.g. investments in science and R&D, and in turn innovation and economic performance (Freeman, 1995). Science is necessary but not sufficient for innovation success. An additional aspect of this debate is that it is not obvious that narrow, ‘science-based’ innovation is more important for competitiveness and economic growth than innovation in a broad sense, and therefore adhering to the narrow approach can result in misleading policy conclusions (Johnson, Edquist, & Lundvall, 2003; B.-Å. Lundvall, 2007). Moreover, the industrial structure and innovation dynamics of a sector can influence which perspective is most suitable.

These considerations imply that even though innovation foresight (broad approach) should be pursued science and technology foresight are complementary and valuable elements – this is especially true if they are consciously designed to pay attention to interactions between the science system and the innovation system (interactions between sub-system and overall system).

3.4 Conclusion
The reviews reflect that the progress in innovation studies has influenced the rationales for foresight and in turn the practice and understanding of foresight. Foresight has gone through a similar pattern of change – from supply push towards gradually/increasingly trying to include elements of demand, and the inherent complexities of such processes. These reviews have addressed the research questions “What is the innovation-system approach?” and “What is foresight?” With the introduction of the term innovation foresight and its potential implications it was attempted to approach the research question “What can foresight learn from the innovation-system approach regarding (1) theoretical underpinnings, (2) the importance of context, and (3) including the demand side? The possible implications of such an approach will be further explored in the next section where I will consider indicators for ‘measuring’ innovation foresight.
4 Sectoral innovation foresight in Denmark?

The main implications for foresight from the previous assessment of mutual benefits between foresight and the innovation-system approach are that: (i) foresight should be more concerned with demand-side in knowledge generation, and (ii) it should integrate innovation system analysis (in preparation phase and let it be the organizing principle of foresight) to understand the specific innovation dynamics of the system in question. This implies that I will especially focus on how these elements are represented in the literature and in the empirical cases.

The issue can be formulated as the research question “to what extent is innovation foresight practiced in Denmark at sector level?” To answer the latter question I need to: (a) choose and develop indicators for ‘measuring’ innovation foresight, (b) describe how sector foresight is practiced in Denmark, (c) and evaluate whether this practice can be characterized as innovation foresight according to the chosen parameters.

With respect to point (a) I will review currently used typologies of foresight and evaluate whether the parameters currently used reflect the relevant dimensions of innovation foresight. On this basis I will propose to modify and add parameters. Regarding point (b) I will consider four cases of sector foresight managed by the Danish Technical University (DTU). Point (c) will consist of the application of (a) on (b). The cases are not optimal since they have not all been finished, and the institutional setting is not representative for Denmark. Still, they are able to illustrate relevant points.

We are primarily concerned with foresight at sector level, and foresight that is understood as public policy for innovation to benefit society (the sector) as whole. This is seen in contrast to firm-based foresight which starts from the premise that the final goal is maximizing profits for the firm. This is thus an exploration of foresight as a policy making tool which despite much experience still is in its infancy (R. Barré, 2002). This is even more true when foresight is seen as a policy making tool within the realm of the innovation-system approach.

4.1 Typologies of foresight

Due to the growing diversity of foresight practices there have been made several attempts at developing classification schemes in order to distinguish clearly between the various types. Looking at these reviews of practice and the literature one can find interesting observations but hitherto (according to this author’s knowledge) no one has emphasized the importance and need for integration with innovation-system analysis, and thus implicitly paying explicit attention to user-producer relationships across the domains of science, technology, innovation and production. It is the intention to here present the most recent typologies of foresight, and then add to this on the basis of the concept ‘innovation foresight’. These considerations should result in a template for describing foresight analytically which can be used to reveal some fundamental misunderstandings in foresight practice given that the ultimate goal of doing foresight is to stimulate innovation activities and in turn economic performance of society as a whole.

Here I will (i) present a selection of proposed parameters for categorizing foresight on the basis of recent review articles (R. Barré, 2002; EFMN, 2009; Michael Keenan & Popper, 2008; Porter, 2010; Yuan et al.,

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6 Developing methodology for how innovation system analysis should be integrated in foresight is beyond the scope of this paper and constitutes another line of work that is currently also being pursued.
The parameters reflect dimensions of foresight. These are categorized in two main groups. One concerned with the ‘content’ of foresight which basically refers to the design. The other dimension is concerned with the ‘process’ of foresight which can be understood as elements influencing the process. This distinction is not new and is widely applied (Martin & Johnston, 1999; TFAMWG, 2004; Wiek et al., 2006). The parameters I will consider in relation to content are: (1) motivation, (2) thematic classes, (3) horizontal versus vertical, (4) system levels, (5) time horizon, (6) rationale/objective, (7) output. Related to the actual process of foresight other parameters are emphasized. They are: (1) customers, (2) extensive versus exclusive, (3) number of participants, (4) diversity of participants, (5) sponsors, (6) duration of foresight, (7) process outputs.

4.1.1 Content of foresight

(1) Motivation: In terms of motivation foresight can be distinguished between extrapolative and normative. The extrapolative foresight takes the present as point of departure. Given the information we currently have what would we then expect to happen in the future. On the other hand the normative approach identifies a desirable future and ‘backcasts’ this vision on the present. It targets to identify paths from the present to arrive in the desirable future (Porter, 2010). Both these instruments are relevant for innovation foresight but it would, in my opinion, be biased towards the extrapolative (even though the word seems wrong in this context).

Regarding Thematic classes (2) Barré (R. Barré, 2002) divides foresight into four thematic classes: (i) technology areas (technologies, possibly with their scientific components, underlying capabilities, use function); (ii) activity sectors (economic or industrial, activity cluster); (iii) public functions (areas of public action and policy); and (iv) strategic issues (challenges, problems, horizontal questions, societal goals). He argues that technology areas and activity sectors are of ‘supply-push’ nature whereas public functions and strategic issues are more demand-oriented (demand-pull). This may be true in foresight practice but the distinction is not obviously helpful. Each thematic class – even though they will overlap – can be conceptualized as an innovation system due to the openness and recursiveness of these systems. It is not important whether actors involved in the system are public or private; what matters is innovation dynamics where both elements of push and pull and the linkages between them must be present. Barré does argue though that something similar to a system view is needed for sector foresight which must lie in between pull and push. Still, the issue becomes to distinguish between different forms of innovation systems where the most important one for this work is between technological innovation system (TIS) and sector innovation system (SSI).

In TIS focus is especially on promoting and spreading a specific new technology. It thus has little focus on implementation of technology, the economic impact of it, and the social and institutional barriers that this may face. The focus on technological domain implies that a TIS will cover a range of different sectors and not be geographically confined (Coenen & Díaz López, 2010). This can crudely be understood as the area for technology foresight. The SSI focus explicitly on firms/organizations embedded in the socio-technical environment. A SSI can be defined as a “sectoral system of innovation and production is composed of a set of new and established products for specific uses, and a set of agents carrying out activities and market and
*non-market interactions for the creation, production and sale of those products*” (Malerba, 2004, p. 16)\(^7\).

Taking an existing sector as point of departure implies that several different types of technologies are involved (it is not geographically defined either, though). Since this work is concerned with sectors the SSI approach will be emphasized. In principle this implies that the starting point for analysis becomes the organizations and firms (actors) operating within a given SSI instead of taking a technological domain as starting point.

Regarding the (3) horizontal versus vertical nature of foresight, horizontal foresight is normally the wide foresight in an international perspective, covering a broad range of topics and issues which are not restricted to specific disciplines, sectors, institutions, geographical areas, etc. The aim is to provide insight and give their opinions on important new developments and societal challenges that can be taken into consideration some areas for future strategic research. The vertical foresight is limited foresight focused on a specific discipline, sector, geographical area etc. The aim is to identify, justify and describe Danish potentials and development opportunities within the current area of focus in an international perspective, which can be taken into consideration of the allocation of research funds.

Foresight processes and research prioritization requires an overview of very complex problems. Foresight Projects can be implemented on many different system levels (4), and the chosen level depends, amongst other things, on the purpose and resources of the foresight process. The process often begins with a classification and definition of the system which is addressed. System definition is an analytical image of reality, a construction that can be used to structure and define a problem. This aims firstly to create a mutually accepted understanding of what is included in the foresight process, and secondly, the basis for structuring the further process. The definition and choice of level thus affects the choice of methodology, data collection and stakeholder involvement in the subsequent steps in the foresight process.

System Levels:
(i) The micro level is the individual level, ie. individuals, some small businesses, individual (smaller) institutions, a residential area, a single technological field; (ii) Meso levels by are oriented towards sub-national groupings, whether it be interest organizations, trade associations, sectors, cities, regional areas, groups of technological fields, etc; (iii) Macro-levels by being oriented towards national and social contexts, it may be of national strategic plans for major cross-cutting development or responsibilities; (iv) Global levels by looking ahead to the global level, it may be areas or challenges related to international or supranational alliances or organizations.

Regarding (3) and (4), the current focus on sector innovation foresight implies that this type of foresight will be vertical, and that it will primarily be oriented towards the meso level. Still, since sectors are not geographically defined (in contrast to clusters) this type of meso level will most likely also involve cross-sectional, national and global perspectives.

It is relevant to be specific about what time horizon (5) is applied to foresight. It is common to distinguish between short term, medium term and long term. The understanding of the length in terms of years of the three time horizons is difficult to generalize, since this depends on the focus area and the purpose of

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\(^7\) This definition acknowledges the often intrinsic ties between production and innovation activities. Still, using existing products as definition may provide difficulties in the case of emerging demand and products where there is technological and market uncertainty. Ex-ante boundary setting of the system may therefore miss out on important factors and actors driving innovation (Coenen & Díaz López, 2010).
foresight. For example, foresight oriented towards infrastructure for energy supply have a different understanding of the development of short and long term than areas with rapid change as ICT. Still, an overall estimate of time horizons could be: (a) short term: ca. 1-5 years; (b) medium term: ca. 3-15 years; (c) long term: more than 20 years; (d) very long term: longer than 50 - 100 years. Given that the innovation-system approach has refrained from thinking about anything but the very short-term future, the longer term perspectives may be an analytical contribution to that framework. The time horizon applied can also reflect the relative emphasis given to the future opportunities in the sector (longer-term) or current challenges (short-term). The demand for knowledge from actors in the sector will most likely be strongest regarding resolving current challenges (ref.). The close relation between production and innovation in the innovation-system approach and the general perception innovation as a problem-solving activity further supports emphasis on the short-term. It should be possible to integrate the longer-term perspectives of foresight with current challenges. It is, in principle, the nature of innovation foresight to address challenges and opportunities (equally) in a given (sector) innovation system. This is an additional parameter that is worth considering.

As seen earlier there are many different types of rationale and objectives (6) for doing foresight. As argued in previous sections the main rationale for innovation foresight is to ‘strengthen’ the innovation system in questions. The latter implies that regardless of which specific means (sub-goals) a foresight may have they should be systematically linked to both immediate performance (IS) and ultimate goal (social prosperity).

There may be several types of results and outputs of foresight (7). One dimension is the codified results and outputs related to the finished product which is different from process-related outputs as for example, networking and communication. According to a recent global foresight survey by the European Foresight Monitoring Network the most frequent codified outputs are (listed hierarchically): policy recommendations, scenarios, description of key technologies, technological roadmaps, analysis of development trends and the driving forces behind, research priorities and extrapolation (forecast) (EFMN, 2009).

4.1.2 Process of foresight

The parameters (besides the actual facilitation instruments) that influence the process of foresight primarily concerns which actors are included in the process in the form of customer, participants and sponsors.

(1) Customers: the nature of the customer (actor requesting the foresight) is often reflected in the motivation and purpose of the foresight and in turn in its design. Customers are often a mix of: (i) public administration and elected officials (politicians); (ii) businesses and industries; (iii) research institutions; (iv) unions and industry associations; (v) interest groups; (vi) ad hoc constellations may be relevant in connection with special or new initiatives.

(2) Extensive versus exclusive foresight: participation in foresight processes are characterized as either extensive or exclusive (Salo, Könnöä, & Brummer, 2008): (a) Extensive involvement of stakeholders and actors refers to a broad and open involvement of a larger number of people, and perhaps as a process with an open invitation to all who wish to contribute to the process. The reasons may be required to allow all views to come forward or a desire to create ownership of foresight results among a wider circle of actors and stakeholders; (b) Exclusive involvement of stakeholders and actors means a closed process where only a small group of specially selected participants are invited. The reasons may be the desire for a quick and
efficient process, or a requirement for a balanced representation of different groups of actors and stakeholders.

(3) Number of participants: Several people give input to a foresight through participation in workshops, questionnaires, etc. The number of participants in the foresight process is a measure of how broad a foundation the foresight rests on, and how widespread knowledge about the foresight is (diffusion). It may be difficult to gather reliable information about how many people that in one way or another has participated in or contributed to working groups, expert panels, workshops, questionnaires, open meetings, etc. The European Foresight Monitoring Network uses the following categories of participants: (a) <50 participants, (b) 51-200 participants, (c) participants 201-500, and (d) > 500 participants (EFMN, 2009).

(4) Diversity of participants: an important input in a foresight is the insights generated by the views of actors and stakeholders with different institutional affiliations. The diversity can be difficult to quantify. An expression of diversity will be representatives from: Research institutions, advisory firms, industries and businesses, Government Offices and administration (ministries, regions, etc.); Professional associations and federations and others (NGOs, individuals).

Sponsors to foresight projects (5) can be very different, and foresight projects can also be financed by one or more sponsors. Typical sponsors are public authorities (ministries, municipalities, etc.), public research institutions, companies and non governmental bodies. According to the European Foresight Monitoring Network are public authorities, the main sponsor of foresight projects (EFMN, 2009). The sources of finance are relevant to note because they are likely to reflect particular interests that may influence design of foresight.

With respect to innovation foresight point (1) is given in as much as we are concerned with public policy foresight in the current work. The latter is partly true for point (5) but it is still relevant to know exactly which entity, office or individuals that sponsor the foresight. Points (2) and (4) should be given by the sectoral innovation system analysis. The definition of the innovation system in question will identify which core actors are relevant to include and the degree of exclusiveness. The latter will naturally focus on equal representation of users and producers of knowledge (in the defined system), and include actors that are affiliated with the organizations controlling necessary infrastructure and other structural elements (public sector). Point (3) is difficult to say anything specific about a priori but, ceteris paribus, the larger the number of participants, the more robust the output may be due to the increased diversity of and competition between ideas. Representation of diversity (qualitative) in the system is not necessarily reflected in number of participants (quantitative).

The duration of the foresight process (6) will vary depending on the topic, and results for example used here and now in relation to an urgent problem or whether there is a need for a process with a greater degree of dialogue and interaction. Porter (2010) uses the following three categories of length of process: Days, Months and Years.

The processual outputs of foresight (7): in contrast to the tangible outputs of foresight discussed above, process outputs are intangible and difficult to measure. This concerns the ‘wiring up’ of innovation systems, and is thus central to the idea of innovation foresight. The wiring up can take place via (i) building of new
couplings, linkages and networks, (ii) creation a shared vision to strengthen coordination of decision-making and investments, (iii) bring new actors into the debate, (iv) diffusion of information and enlighten the public via debates, (v) competence building in participants. These are very similar to the 5Cs (Martin & Johnston, 1999).

As pointed out by Georghiou and Keenan the rationale for foresight is closely related to what one considers as an output, and thus in turn which indicators one would use to document whether goals are achieved or not (L Georghiou & Keenan, 2006). In a broad approach to innovation foresight one would focus ‘equally’ on process (network building, collective learning, competence building, vision building) and product benefits (reports, dissemination of reports, recommendations to policy, research agenda/priority list, roadmaps, description of technologies, etc). The latter tends to be more explicit and codifiable while the former, though not tacit, tends to be harder to measure, and there is in turn no guarantee than the process benefits will actually have an impact on firm innovation in the end (if there is one). We therefore recommend that sector development strategy should target both process and product benefits, or as a minimum consider how this particular piece of strategic intelligence complements similar activities and take that into account. The purpose is not to spend resources or unnecessarily complicate things; it is about effectiveness (not efficiency).

4.1.3 Summing up

On basis of the above review it has been possible to identify and ‘mould’ some parameters that can be used to examine whether innovation foresight (sectoral) is practiced in the selected cases. The parameters are summarized in the two tables below, and currently constitute a template for describing foresights. The discussion above has furthermore illustrated some preliminary impacts of accepting the innovation-system approach as rationale and theoretical basis for foresight. One general implication is that innovation system analysis must be integrated into the planning phase of foresight. Such an analysis would, as illustrated above, be decisive for a range of the parameters mentioned below. The suggested implications are merely crude and tentative suggestions that must be further developed.

<table>
<thead>
<tr>
<th>Content of foresight</th>
<th>Options</th>
</tr>
</thead>
</table>
| Motivation           | • explorative  
                       | • normative |
| Thematic class       | • Sectoral innovation system (SSI)  
                       | • Technological innovation system (TIS) |
| Horizontal vs. vertical (SSI vs. TIS) | • Vertical, when SSI  
                       | • Horizontal, when TIS |
| System level         | • Meso, interacting with micro, macro and global |
| Time horizon         | • short (1-5 years)  
                       | • Medium (3-15 years)  
                       | • long (> 20 years)  
                       | • very long (longer than 50-100 years) |
| Rationale            | • strengthening/building innovation systems (primary)  
                       | • identify future options for research and innovation (secondary)  
                       | • highlight the strengths of research and innovation systems (secondary)  
                       | • bring new actors into the strategic debate (secondary)  
                       | • construction of new transversal network and collaborate (secondary) |
| Output (tangible)    | • policy recommendations  
                       | • scenarios |
The considerations made above – concentrated in the template – will be used to analyze the selected case studies in the next section.
5  Sector development program at DTU

The structure of the section will be as follows. Since a general introduction to the sector development program was given in the main introduction, I will start with the review of four sector development projects on the basis of the innovation foresight template developed above. Thereafter, I will present supplementary information about the management of the sector development program that complements the findings in the case studies, and make analytical assertions on the way. Lastly, I will propose some reasons to why innovation foresight seems to be absent, and suggest points for improvement and further research.

Methodology

The data used originates from written material about the various projects, the website of DTU’s office for public sector consultancy (DTU-PSC), and 3 interviews with key personnel (4 persons) at DTU-PSC conducted in January 2012. The interviewees are Jan Molzen (head of section), Steffen Syberg, Nikoline Kieler and Hannah Wermuth. A phone-interview with Jonas Orebo Pyndt from Danish Industries was made a supplement to the former. The interviews were designed as semi-structured and applied open-ended questions. The questions were designed to meet two ends: (1) one is the general perception of their jobs and the sector development program; (2) the other is aimed at specific projects where I emphasize the organization of the actual process of the foresight they make. In the latter the main question was “can you describe the main challenges and problems experienced in this project?” Hence, the description below will reflect this focus.

5.1  Individual sector development projects

The office at DTU-PSC has existed only for about 1 year, and has currently only officially finished one project of sector development strategy (cleaning technology in the food sector) while others are work in process and still others have been terminated. I will focus on the process of planning of the sector development strategy to see whether the principles of innovation foresight have been involved. With this focus the projects currently ongoing and those that failed hold valuable lessons also. Each project presentation will consist of a brief project description (content) and a description of the process of the project. For each project the foresight template developed above will be applied.

5.1.1  Cleaning technology in the food sector

This project is the only one that has been formally finished within in the sector development program. It consists of collaboration between DTU, DTU-PSC and slaughter and dairy industries in Denmark. The purpose of the project was designated to identify and report a number of key technological challenges and opportunities associated with handling of cleaning processes and technologies in slaughterhouses and dairies. The final report recommends a number of research and development activities that broadly covers the industry’s challenges and increases the competitiveness of slaughterhouses and dairies by developing and applying future clean technologies and processes (DTU, 2012).

Process

The project originated as a response by Danish Industries (DI) (on behalf of a few large firms in slaughter and dairy industries) to a call issued by DTU about that their new department of sector development was looking for projects and partners.
During interviews the project-responsible personnel (SS and NK) described the following challenges: (i) during the workshop it was a problem that firm representatives were not sufficiently well-informed to engage fruitfully with the researchers from DTU due to a lack of detailed information about their production; (ii) the DTU-PSC staff had doubts about the sincerity/dedication of firms to the project. One firm indicated that this project was not of high priority because water was not that expensive in Denmark so it wasn’t a high priority despite water scarcity and efficiency was one of the main motivations for the firms to start up the project in the first place. Another firm indicated that these types of projects are the cheapest way for firms to develop research projects and that they therefore were present mostly to see and hear new things rather than because they had a concrete and serious agenda/problem to be solved in collaboration with researchers from DTU; (iii) firms may face perverse incentive structures with respect to for example disclosing information. A firm may participate to hear other firms’ information. There is thus a situation of rivalry that one must think of. The DTU-PSC staff suspects that such issues can undermine the process of the project.

Another challenge mentioned is that some of the problems brought in by firms were evaluated by DTU as not having sufficient ‘research/innovation height’ for the sector development program. As one DTU-PSC employee said: DTU is not a consultancy firm, DTU does not go into knowledge diffusion of known technology. This is the job of other organizations.

A regret at DTU-PSC is that sub-suppliers of the big firms were not included in the project. They were left out as a consequence of a unanimous collective decision. The main reason given was that it would distort the focus of the workshop which was already rather vague. Still, since these most likely must be involved in developing new technology it would have been beneficial to have them onboard.

<table>
<thead>
<tr>
<th>Content of foresight</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motivation</td>
<td>Explorative</td>
</tr>
<tr>
<td>Thematic class</td>
<td>Oriented towards challenges in the agricultural sector but a holistic/systemic sector perspective was not applied. It is thus best described as an ad hoc thematic class.</td>
</tr>
<tr>
<td>Horizontal vs. vertical (SSI vs. TIS)</td>
<td>Since focus was rather narrow the sector development project has a vertical design.</td>
</tr>
<tr>
<td>System level</td>
<td>Meso level. It is below sector level but above the level of individual firms.</td>
</tr>
<tr>
<td>Time horizon</td>
<td>Short and medium</td>
</tr>
<tr>
<td>Rationale</td>
<td>“Identify future options for research and innovation” as a mean towards improving competitiveness of the industries which can broadly be translated into stimulating innovation in the industries and thus strengthening the innovation systems.</td>
</tr>
<tr>
<td>Output (tangible)</td>
<td>Description of key technologies Analysis of trends and drivers Research priorities</td>
</tr>
</tbody>
</table>

**Table 6: Content of foresight parameters**

<table>
<thead>
<tr>
<th>Foresight process</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customers</td>
<td>businesses and industries (participating actors) research institutions (DTU)</td>
</tr>
<tr>
<td>Exclusive vs. extensive</td>
<td>Since no system was defined it is difficult to access this parameter. Still, seen from a sector/system perspective this sector development project was exclusive because only very few actors were involved and given voice.</td>
</tr>
<tr>
<td>Number of participants</td>
<td>&lt;50, it seems that only 3 large, industry-dominating firms were involved (to be confirmed)</td>
</tr>
<tr>
<td>Diversity of participants</td>
<td>Research institutions (DTU)</td>
</tr>
</tbody>
</table>
### 5.1.2 New materials

This project is still ongoing. It has been redesigned due to challenges of articulating demand (my formulation). The project is motivated by the general prospects of developing and using new materials in a range of industrial applications within the areas of casting, assembling and designing, powder metallurgy, composites, ceramics and electronic materials, and wear, surface and protection materials.

**Process**

The project originated from interaction between DTU and DI where DTU was looking for a project and DI has an immediate interest in new materials as area holding much prospect for their members. Subsequently DTU-PSC organized a DTU-internal workshop with the intention of mapping competences in the area of new materials. The workshop involved 7 university institutes and resulted in a selection of areas of interest that are mentioned above. This list of areas (not presented in full here) was of a rather general nature in terms of details and actual problem-solving. It was brought to DI who was then supposed to enroll firms as participants for a research project.

DI presented the call in 8 business societies without any success. Firms were unable to react with something concrete. All firms found it relevant and interesting, but they couldn’t connect the areas identified by DTU with concrete problems and challenges in their current production.

The project has been on stand-by for about 7 months due to the stalemate in communication. Recently DI has employed a man to focus on this failure of communication explicitly. His task has been to call firms directly and talk to them about the project and explain in more detail what the basic idea is. Now DI has identified 12 firms who are willing to participate, and several workshops have been planned.

<table>
<thead>
<tr>
<th>Content of foresight</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motivation</td>
<td>Explorative</td>
</tr>
<tr>
<td>Thematic class</td>
<td>New material is neither a sector nor a technology area – it is thus neither TIS nor SIS. Still, the approach of mapping a competence list which is passed on to firms reflects a linear and non-systemic understanding of innovation. With an innovation-system approach in mind it is not difficult to understand that firms did not react constructively to the list. On the other hand of a system where to be defined, it would have to be much more narrowly defined in order to be meaningful.</td>
</tr>
<tr>
<td>Horizontal vs. vertical (SSI vs. TIS)</td>
<td>Both and none, see above.</td>
</tr>
<tr>
<td>System level</td>
<td>Meso, interacting with micro, macro and global</td>
</tr>
<tr>
<td>Time horizon</td>
<td>n.a.</td>
</tr>
<tr>
<td>Rationale</td>
<td>“Identify future options for research and innovation” as a mean towards improving competitiveness of the industries which can broadly be translated into stimulating innovation in</td>
</tr>
</tbody>
</table>
the industries and thus strengthening the innovation systems.

The linear approach also indicates that a rationale is getting firms to sponsor DTU research rather than having researchers supporting innovation in firms.

### Output (tangible)

n.a. - but intention is to make a report that focuses on:
- Description of key technologies
- Analysis of trends and drivers
- Research priorities

### Table 8: Content of foresight parameters

<table>
<thead>
<tr>
<th>Foresight process</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customers</td>
<td>research institutions, unions and industry associations</td>
</tr>
<tr>
<td>Exclusive vs. extensive</td>
<td>Exclusive in the sense that firms were included only late in the process</td>
</tr>
<tr>
<td>Number of participants</td>
<td>&lt;50 until now.</td>
</tr>
<tr>
<td>Diversity of participants</td>
<td>Only DTU researchers and while DI has tried to sell the ideas of DTU</td>
</tr>
<tr>
<td>Sponsors</td>
<td>DTU</td>
</tr>
<tr>
<td>Duration of foresight</td>
<td>n.a.</td>
</tr>
<tr>
<td>Output (intangible)</td>
<td>n.a.</td>
</tr>
</tbody>
</table>

### Table 9: Foresight process parameters

#### 5.1.3 Prevention of mould

The idea originated internally at DTU but was well-received by several industry associations and firms because mould is seen as a big problem in construction and housing with severe health implications.

The initial steps led to meetings internally at DTU where it became clear that the knowledge about the sources and consequences of mould was simply too limited to engage in applied research. Instead new research networks were formed at DTU that formulated research projects on (i) sources of mould and (ii) mould and health (a medical doctor attached). These have been approved with budgets of about 2.5 million DKR.

It thus never became a program for sector development as such but it did lead to internal cross-departmental networks. Still, the initiative reflects (again) a process that starts internally at DTU – either by researchers approaching DTU-PSC or by DTU-PSC approaching researchers because they have a general idea of a social/industrial challenge they want researcher to respond to by making a competence map and identify areas of interest which in turn will be presented to firms. Also, in this case the latter approach didn’t work with respect to the sector development agenda. As indicated by the staff at DTU-PSC, this project was too science-based (at its current stage).

#### 5.1.4 Aerospace infrastructure

There is at present being invested two-digit billions (in Euro) in building a comprehensive European space infrastructure. These are primarily two systems: (i) Satellite navigation system Galileo, Europe's answer to GPS, but have a number of for-improved features that provide new opportunities, and (ii) Earth Observation System GMES (Global Monitoring of Environment and Security), which is an operational system of satellites in different wavelength ranges, which can provide data and information on a variety of conditions.
on land, on / in the ocean and the atmosphere. There is a variety of commercially interesting applications of these two systems - especially in combination with each other and possibly with integrated satellite communications. Both systems will be operational within the next 2-3 years. This means that for Danish industry (and the public sector) there is now a “window of opportunity” in terms of getting ready to take advantage of these new space-based infrastructures, such that the Danish society can benefit from these systems from the outset and thus a stronger position in international competition.

**Process**

DTU Space (institute) first approached DTU-PSC with this idea in 2011. DTU Space insisted that the growth and appearance of these technologies would have the potential to generate vast business opportunities for Danish firms – if these firms would be prepared. The idea was initially rejected due to its lack of business partners. Later DTU Space returned with a private partner CENSEC (Center for defense, space and security, an industrial cluster). This created interest in DTU-PSC and soon more stakeholders emerged both from within and outside DTU. There are now a number of stakeholders with an interest in the project.

The second week of February saw the first workshop of the project which focused on identifying relevant core competences at DTU, research gaps and potential synergy effects among internal stakeholders with respect to research projects (all participants are DTU researchers). A second workshop is scheduled already in the hope that some research projects will come out of the first workshop that in turn will be presented to business stakeholders.

In a sense it is a nearly classic top-down science-push project, but it does seem to have interest among business stakeholders (even though a niche in whole industrial structure). Given that this sector is extremely science-based the current approach might be successful but it still isn’t a sector development strategy with focus on innovation. The latter is reflected in the sequencing of steps in the process which starts internally at DTU and only thereafter looks for potential private partners.

It is a tradition at DTU to approach university-industry collaboration in this manner but the idea of the sector development program is to: (1) make a systematic sector analysis, (2) ask stakeholders to identify problems and opportunities, (3) and only then look for the possible solution – instead of, as the current practice is, do it the other way around.

**5.2 General information about the PSC office**

During the interviews several interesting points emerged. These are relevant for the discussion of innovation foresight because they complement the observations made in the individual cases.

**5.2.1 A sector development program**

The staff at DTU-PSC was not certain why the word sector is applied instead of for example technology, but they were positive that the intention with the program is to orient the activities of DTU towards societal challenges to a larger extent. It can be seen as problematic that key staff does not know the difference between taking a technology focus (TIS) and a sector focus (SSI).
5.2.2 Idea generation process

The idea generation process and selection of ideas/projects takes place in continuous interaction with potential partners as industry associations and policy makers at regional and national level. Also, the general zeitgeist influences areas of interest such as health, climate change/energy and productivity. The latter can also be formulated as the grand social challenges of our time. When the initiative was started DTU-PSC sent out a broad call for collaboration to say that it existed and was looking for ideas. The reactions to this have been the main source of project ideas since. This process has contributed to that a proper sector focus has been absent in their work because those who react to this call are individual firms or industry associations on behalf of a few large, competent firms. These constellations of actors do not qualify as a sector. Consequently, proper sector analysis has not been conducted independently of participants.

There is no particular model for these projects. Most of them have been initiated due to interest from industry associations after an initial call from DTU-PSC that they were looking to engage with firms (and that they had resources).

5.2.3 Innovation ‘height’ and Conflict of interest

According to the staff, DTU-PSC is focused on high-technology areas and firms because only these can engage in projects with research potential. According to the head of section innovation is more about knowledge diffusion, and therefore not an area of interest for DTU which is only interested in high-tech firms and/or radically new technology. Innovation is the concern of other types of organizations (public technology institutes for example).

This reflects that DTU-PSC is more concerned about directly involving scientific research at the frontier than about innovation, and it reflects a conflict of interest. The staff stated that their work is not primarily about stimulating innovation in firms. Instead is it about generating research projects for DTU, and if this can be combined with innovation in firms, then even better. This reflects a generic conflict of interest for DTU-PSC regarding their potential different roles. Should they support firms or should they support researchers’ and DTU’s desire for research funding.

The head of section described the different interests involved as: (i) DTU-PSC as an office wants a tight and well-managed project process and to do a good and efficient job. DTU-PSC will mainly be evaluated by management at DTU on its ability to attract research projects; (ii) DTU as an organization desires funding for research. Sector development is a possible way to obtain financing, IPR and publications; (iii) the society as such desires innovation for economic growth inter alia via the development of economic sectors which is reflected in the four intermediate goals of the sector development program listed by DTU-PSC at their website. Obviously, the science focus of DTU can conflict with the intentions inherent in the sector development program.

The perception of innovation in DTU-PSC can be conceptualized as, at best, an exclusive interest in science-based innovation, which in turn limits the scope of sector development to dominantly science-based sectors. Thus, what is going on is only partial innovation foresight – it is based on the narrow version of the innovation-system approach. Being more critical one can argue that the system perspective is absent, and that DTU-PSC perceives innovation according to the linear model of innovation where it is seen as the spill-over
effects from science. The creation of the sector development program reflects a desire to move beyond the linear model towards the systems model but so far without much success.

The information described also indicate a misunderstood perception of innovation at DTU reflected in the ideas that: (a) science, technology and innovation can be clearly separated; (b) that innovation ‘height’ can be easily assessed; (c) that apparent low-tech sectors are not of interest for DTU – because it is thought that DTU can’t make money by engaging in these projects. This mentality was also reflected in that the majority of the personnel were of the opinion that most of the problems firms bring to the table are more suitable for ‘student projects’ (it is unclear whether this has been explicitly proposed). It might be true that firms’ problems are not suited for research projects but there are at least two dangers involved in this attitude: (1) firms will feel disrespected if a student project is proposed which will damage the possibility of a longer term relation based on trust between firms and DTU; (2) who evaluates the innovation height of problems? It is alarming if it is the generalists at DTU-PSC that do not have any technical insight. In general, the reluctance to deal with innovation as opposed to science and technology seems to be a mental barrier for approaching the goals set out for the sector development program.

5.2.4 Lacking articulation of demand

Related to the latter paragraph the staff expressed frustration about the competences, willingness and/or demand from industries and industry associations. Thus, apart from confusion about conflicts of interest, perception of innovation and of means and ends, DTU-PSC is possibly confronted by a lack of quality partners on the receiving side of knowledge – from the users. According to the staff at DTU-PSC the industry associations are not optimal partners because: (a) they most often do not represent a homogeneous group of firms (a meaningful sector) instead they have very heterogeneous members in terms of size, industry, capabilities, interests and problems, (b) they do most often not see it as their role to facilitate university-industry interaction, (c) and, maybe related, they do not seem to have the necessary competences to engage in such projects because the staff hired is mainly generalists trained in social science, so they do not have detailed information about and understanding of the reality of firms (technological problems and industry bottlenecks) due to bias in education and the high level of generality in industry associations. These points imply that it can be difficult to establish meaningful interaction between DTU-PSC and industry associations because the staff at both these offices is made up by generalists and not engineers with knowledge about technological issues. The lacking articulation of demand (problems and challenges in terms of science) of users is a structural problem which can hinder the communication between firms and researchers (a cognitive barrier). Thus, there seems to be a need for quantity and quality of ‘bridging organizations’ to facilitate communication across innovation sub-systems (Boon, Moors, Kuhlmann, & Smits, 2011; Kaufmann & Tödtling, 2001).

5.2.5 Proposals improvement

If DTU-PSC chooses to continue with a science focus it should as a minimum take the innovation system approach seriously by rejecting any tendency to think in terms of the linear model of innovation, and moreover when/if making a narrow system analysis DTU-PSC should explicitly consider how the narrow system interacts with the broader system.

Still, there can be a problem in focusing exclusively on high-tech sectors (OECD definition) in Denmark. This is so because the industrial structure in Denmark is dominated by low-tech sectors and characterized
SMEs that rarely have competences for engaging in science project collaborations. Furthermore, it is worth remembering that much of Danish economic development has historically (and presently) been based on innovation in low-tech sectors as agriculture, food and drink, fishery, ship building and transport.

If DTU-PSC decides to embrace the broader approach to innovation and includes low-tech sectors and SMEs in the sector development program they will face a range of different challenges. This would require a change of mentality at DTU and increased collaboration with other innovation-related offices internally at DTU.

Moreover, there is lacking a conceptual clarification of causality between the activities/goals of DTU-PSC listed on their website, the intermediate goals (improved innovation system), and in turn the ultimate goal of (rationale of having a technical university) creating innovation, competitiveness and economic growth in society. Especially a discussion and clarification of the terms innovation, competitiveness and economic growth and their relation would be beneficial for the department.

It might be worth considering which types of sectors in Denmark are more or less suitable for this science-push approach as practiced by DTU-PSC.

Second to ideally the sector development program can be seen as aiming at aligning the science and technology system (narrow) with the needs of the broader innovation system. But this also requires a system understanding both broad and narrow so you know what you limit yourself from analyzing.

5.3 Conclusions

On the basis of the above I can conclude that sectoral innovation foresight is not practiced in the cases presented despite formal intentions. A prior system analysis was not conducted in any of the cases. This also implies that the system of interest was not defined (ex ante). The analysis illustrated some structural barriers to innovation foresight (intermediate organizations and articulation of demand) and some limits of science foresight and technology foresight.

It is possible that the dominant perception of innovation at DTU-PSC is problematic in the sense that it can function as a barrier for implementing the program (given that it wants to achieve innovation).

DTU, and similar organizations, must understand their role within the larger innovation system in order to fulfill potential. Science foresight, technology foresight and innovation foresight are not equally valuable approaches or models for innovation policy (with the purpose of stimulating economic growth) – it is not about choosing. It is about understanding one’s position and actions within a given system setting.
6 Conclusion

6.1 Innovation foresight
The reviews reflected that the progress in innovation studies has influenced the rationales for foresight and in turn the practice and understanding of foresight. Foresight has gone through a similar pattern of change – from supply push towards gradually/increasingly trying to include elements of demand, and the inherent complexities of such processes. These reviews have addressed the research questions “What is the innovation-system approach?” and “What is foresight?” With the introduction of the term innovation foresight and its potential implications it was attempted to approach the research question “What can foresight learn from the innovation-system approach regarding (1) theoretical underpinnings, (2) the importance of context, and (3) including the demand side? The possible implications of such an approach will be further explored in the next section where I will consider indicators for ‘measuring’ innovation foresight.

6.2 Sector innovation foresight at DTU
On the basis of the above I can conclude that sectoral innovation foresight is not practiced in the cases presented despite formal intentions. A prior system analysis was not conducted in any of the cases. This also implies that the system of interest was not defined (ex ante). The analysis illustrated some structural barriers to innovation foresight (intermediate organizations and articulation of demand) and some limits of science foresight and technology foresight.

It is possible that the dominant perception of innovation at DTU-PSC is problematic in the sense that it can function as a barrier for implementing the program (given that it wants to achieve innovation).

DTU, and similar organizations, must understand their role within the larger innovation system in order to fulfill potential. Science foresight, technology foresight and innovation foresight are not equally valuable approaches or models for innovation policy (with the purpose of stimulating economic growth) – it is not about choosing. It is about understanding one’s position and actions within a given system setting.

6.3 Points for further research
It would be both relevant and interesting to consider more sectoral innovation foresight cases in Denmark and internationally.

The proposed need for bridging organizations in the Danish innovation system should be further explored because it is an issue that potentially can hamper any initiative from DTU-PSC.

Also, the suggestions made above regarding innovation foresight is merely a first tentative step towards initiating a constructive dialogue between the broad, interactive learning-based version of the innovation-system framework (developed in Scandinavia) and the more recent foresight practices. There is potential for making further steps in this direction. Some of the more obvious are: (i) shift focus towards what the innovation-system framework can learn from (innovation) foresight; (ii) develop a much more concrete tool for innovation-system analysis and how to integrate this in a practical sectoral foresight (in progress); (iii) integrate relevant elements into the innovation foresight concept from the rich research literature that exists on foresight more broadly – social inclusion/participation and democratization of innovation policy is of special interest (to the author).
7 Appendix

<table>
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<tr>
<th>Text Box 1: Definitions of an innovation system.</th>
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<tbody>
<tr>
<td>“... The network of institutions in the public- and private-sectors whose <strong>activities and interactions</strong> initiate, import, modify and diffuse <strong>new technologies</strong>” (Freeman 1987).</td>
</tr>
<tr>
<td>“... The elements and relationships which <strong>interact</strong> in the <strong>production, diffusion and use of new, and economically useful knowledge... and are either located within or rooted inside the borders of a nation state</strong>” (Lundvall 1992a).</td>
</tr>
<tr>
<td>“... The set of institutions whose <strong>interactions</strong> determine the <strong>innovative performance</strong> of national firms” (Nelson and Rosenberg 1993).</td>
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<tr>
<td>“... 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 and Lundvall 1993).</td>
</tr>
<tr>
<td>“... 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 <strong>development, protection, financing or regulation of new science and technology</strong>” (Niosi, Saviotti et al. 1993).</td>
</tr>
<tr>
<td>“... The national institutions, their incentive structures and their competencies, that determine the <strong>rate and direction of technological learning</strong> (or the volume and composition of change generating activities) in a country” (Patel and Pavitt 1994).</td>
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<td>“... That set of distinct institutions which jointly and individually contribute to the <strong>development and diffusion of new technologies</strong> 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).</td>
</tr>
</tbody>
</table>
Figure 7-1: System overlap and interaction.
8 Literature


*Research Policy, 36*(7), 949-963. doi:10.1016/j.respol.2007.03.003


