

# Innovation system dynamics and sustainable development - Challenges for policy

**Andersen, M.M.**

*Publication date:*
2004

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

# Innovation system dynamics and sustainable development – Challenges for policy

*Paper in progress*

**Innovation, Sustainability and Policy Conference, 23-25 May 2004**
**Kloster Seeon, Germany**

**Dr. Maj Munch Andersen**
Risoe National Laboratory
Systems Analysis Department
DK-4000 Roskilde, Denmark
maj.munch.andersen@risoe.dk

**Abstract**
This paper argues, that it is necessary to rethink policymaking in the emerging era of a more socially responsible market economy. Creating synergies between RTD policies and environmental policies plays a crucial part in this but it is no easy endeavour. The paper discusses whether the (national) innovation systems theory perspective (NIS) may provide an appropriate analytical framework that may align RTD and environmental policies.

Rather than going into a detailed discussion of policy options, the paper seeks to capture the essence of the innovation system approach and the main policy implications this represents. The innovation system approach while well established in innovation policy is only emerging within environmental policy and research. It is therefore important to consider the underlying assumptions and perception of the industrial dynamics involved.

The paper claims that the NIS perspective represents a new rationale in environmental policy making, particularly concerning the goals, notably the treatment of competitiveness and the delimitation of the system or actors involved. Applying the NIS approach points to the possible trade-off between aiming at (urgent) environmental goals and aiming at building up a (long term) high green innovative capacity. The NIS perspective points to policy programmes with a much stronger focus on knowledge, both when it comes to pulling the demand, pushing technology and making companies' strategic market makers on eco-innovation. And policy programmes that specifically aim to reduce the system failures related to eco-innovation.

There are also some limitations in applying the NIS approach to environmental issues. There tends to be quite a strong focus on technology push perspectives, while market development perspectives are neglected. The NIS perspective forwarded in this paper has sought to overcome this issue by arguing for a three pillar approach, simultanousy focusing on building well-functioning markets, organizational development and coordinated technology development.

The NIS perspective is also important because it places eco-innovation within the wider context of the knowledge economy and the changing competitive conditions it represents. In so doing it helps bring in a more dynamic perspective on societal development, which has so far been treated as a black box in environmental policy. The NIS approach is only emerging in the environmental field, but it carries promising perspectives for a renewal of environmental policy.

## 1. Introduction

In recent years there is a rising interest in integrating environmental and innovation policy, especially at the EU level. Following up on the Lisbon strategy EU's new Environmental Technology Action Plan (ETAP) sends new policy signals in attempting to develop an actual technology policy on environmental issues. The ETAP aims simultaneously "to tap the full potential of environmental technologies for protecting the environment while contributing to competitiveness and economic growth" (COM 2004 38).

It is, however, not fully clear the degree to which ETAP represents a competitive strategy on its own or more of an environmental strategy, i.e. the degree to which eco-innovations are seen as an important contribution to the Lisbon goal of EU "to become the most dynamic and competitive knowledge based economy of the world capable of sustainable economic growth with more and better jobs and greater social cohesion".

This paper does not seek to discuss the ETAP as such. But certainly ETAP has created a topical need to readdress the scope and the means for aligning environmental issues and competitiveness. The paper rather focuses on assessing the implications and potentials in applying a (national) *innovation systems* (NIS) perspective for the simultaneous fostering of innovation and sustainability issues. The core idea of the NIS perspective is to view firm innovation activities within a larger institutional set-up.

The NIS frame is none the least interesting because it forms the basis of much innovation and research policy (OECD, 1999, 2000, European Commission, 2002). But as yet the NIS perspective has only to a very limited degree entered environmental policy making. An exception is the recent Swedish environment led business strategy (NUTEK, 2003). Also the still limited innovation oriented environmental research is only starting to take on an interest in the NIS perspective (see Andersen, 1999, Rand Europe, 2000, Hübner et al. 2000, Hübner and Nill, 2001, Kemp and Rotmans (2001), Kemp, R. (2002), Weber and Hemmelskamp (eds.) forthcoming). NIS researchers tend to have a narrow focus on competitiveness and have only to a very limited degree dealt with sustainability issues (see though Lundvall, 2001). The historic dichotomy between competitiveness and environmental issues still persists and is embodied not only on the market but also in policy regimes and research rationalities.

We need to consider the differences in the underlying assumptions of different policy regimes. The NIS perspective, and hence innovation policy, builds on evolutionary economic theory. Environmental policy, on the other hand, builds on a mixture of neoclassical environmental economics, political science, law and insights from the physical sciences. Creating synergies between these two policy areas is therefore no easy endeavour.

As yet there is little conceptual clarification of what a greening of (national) innovation systems might entail. And empirically we know hardly anything about them. Empirical analysis of environmental innovation systems can inform us on the distinct patterns in the distribution and configuration of (national, regional or sectoral) learning patterns and innovative capacities related to eco-innovation. Such analysis could aid our understanding of innovation system dynamics in important ways. They are necessary before NIS can guide policymaking and strategizing on eco-innovation in a serious way.

The NIS perspective appears by now as a fairly well consolidated frame for (national) empirical analysis as well as policymaking on innovation (though not on eco-innovation). The NIS approach

is appealing to policy makers and policy researchers because it seeks to develop a frame for a holistic policy for all factors and actors influencing on the innovation process. The regulatory regime is given strong emphasis here. However, the broadness and holism of the perspective is also a weakness. The NIS perspective is often misunderstood and referred to in a very broad, general way, also by environmental researchers, taking little account of the micro-theoretical foundations of the NIS approach. The NIS perspective entails, as this paper points to, a specific theory on the co-evolution of institutions, organizations and technology and should not be confused with simply taking a holistic perspective on technological change.

However, the NIS perspective also has some limitations, in part related to the broadness of the concept making rigorous analysis at the micro level difficult (Dosi and Malerba, 1996, Andersen, 1999, Miettinen, 2001). The micro theoretical framework is somewhat limited. This paper joins up with recent trends in innovation theory in synthesizing evolutionary economic and the more strategy oriented knowledge based theory of the firm, also termed industrial dynamics or dynamic capabilities theory, putting more emphasis on economic organization dynamics and firm strategizing (Foray, 1991, Langlois, 1988, 1992, Dosi and Marengo, 1994, Teece and Pisano, 1994, Langlois and Robertson 1995, Loasby, 1996, Teece, 2000).

It goes, however, too far in this policy oriented paper to engage in an in depth analysis of the industrial dynamics of NIS or of greening. For a closer discussion on this see Andersen (1999, 2002). Rather, this paper takes a constructive stance and seeks to point to those core considerations within the NIS approach, which may in important ways guide environmental policy and empirical analysis on eco-innovation. The term “NIS approach” is treated fairly pragmatic. It reflects the core proponents (noticeably Lundvall and Freeman), but also the author’s considerations as to how the NSI approach could be further developed.

There is a way to go before we have clarified how the quite broad modern innovation systems theory may guide policymaking on sustainability issues and the contribution here should be seen as some starting considerations.

The paper attempts to outline a few key analytical perspectives and discuss the derived policy principles from applying the NIS perspective to sustainable development/eco-innovation.

The paper argues, that it is necessary to rethink policymaking in the emerging era of a more socially responsible market economy and that the NIS perspective may play a key role in this. The paper claims that the NIS perspective represents a new policy rationale, a rationale first of all giving *knowledge based innovation* and *competitiveness* a pride of place. Enhanced self-regulation facilitated by a well-functioning national innovation system plays a key role in this approach. The traditional measures in environmental policy making, regulation and fiscal measures, are necessary but not sufficient for integrating environmental issues into the economic process.

The NIS perspective is especially important, if not necessary, in two ways: A) In identifying and breaking the none-green production and consumption practices locked-in to almost all parts of the innovation system. And B) in dealing with systemic change.

There is much emphasis in environmental research on the need for “systems innovation” (e.g. Rennings, 2004). Sustainable development can only come about through larger simultaneous transitions of administration, infrastructure, production and consumption patterns. However, these analysis or policy recommendations tend to neglect the evolutionary and cumulative nature of change. We need to be more specific about the character and dynamics of the innovation processes

involved and investigate into the specific types and degrees of systemic change in the innovation system.

The NIS perspective, putting strong emphasis on the interdependencies, the match and mismatch between the sub-elements of the innovation system, may aid the understanding of the evolutionary nature of the processes of systemic change in the innovation system and help us specify more precisely what "systems" we are talking about and how best to achieve specific kinds of systemic change.

In the section below a few main considerations will be made on the industrial dynamics of NIS and greening. In the subsequent section follows a discussion of NIS inspired policy implications and recommendations.

## 2. NIS and the industrial dynamics of the greening of industry

### The (national) innovation system perspective

An innovation system is defined as "those elements and relations, which interact in the production, diffusion and use of new and economic useful knowledge" (Lundvall, 1992)[1].

The national innovation system (NIS) perspective forms a part of the evolutionary economic theory, aiming to analyze disequilibrium markets hereby making up an alternative economic theory to the predominant neoclassical economic theory. The NIS perspective emerged in the mid 1980's as an attempt to develop a stronger systems perspective on innovation. Quite a range of important evolutionary economists has contributed and lately noticeably the OECD and EC play important roles in operationalizing the frame (Lundvall, 1985, 1988, 1992 (ed.), 2001; Freeman 1987, 1995; Nelson, 1993; Metcalf, 1995; Edquist, 1997, OECD, 2000, 2001a, 2001b, European Commission 2003).

The NIS theory seeks to provide an analytical frame for the analysis of the co-evolution of technology, institutions and organizations (Lundvall, 1992 (ed.); Freeman 1987, 1995; Nelson, 1993; Metcalf, 1995). Hence company innovation is seen in a larger institutional set-up. It is the company and its competitive conditions that form the basis of analysis but the political and other institutional conditions are included in the analysis. In seeking to provide a stronger systems perspective on innovation, the NSI perspective none the least form a basis for policy making. The NIS perspective sees the market as inherently turbulent and characterized by high uncertainty. There are fundamental market imperfections (rather than market failures), which it is the public task to seek to remedy. Market imperfections such as insecurity on innovation potentials for market actors, long commercial maturing, lock-in into sub-optimal technologies and institutions and high switching costs. Conditions that mean that many promising innovations never gain success on the market. This goes particularly for the more radical and systemic innovations.

The NIS perspective is closely related to the concept of the knowledge economy, arguing for the central role of knowledge based competition ((Lundvall, 1992 (ed.); Freeman, 1995; Nelson, 1993; Metcalf, 1995; OECD, 2000). In the face of change markets may be contemplated of as a system for the coordination of the growth of knowledge (Loasby, 1996). The still more rapid innovation, the mobile capital and the revolution of communication caused by the information technology means

[1] Innovation is defined in the innovation literature as a novelty leading to value creation on the market.

changing competitive conditions. Pure cost strategies no longer suffices in the strong global competition. Rather the ability to innovative and seize new market opportunities ahead of others is central. The capacity to learn, i.e. to develop, absorb and apply new knowledge while creatively destructing the old is the key to competitiveness. This goes especially for the affluent, high-cost western economies, which need to find novel parameters to compete on (OECD, 2000).

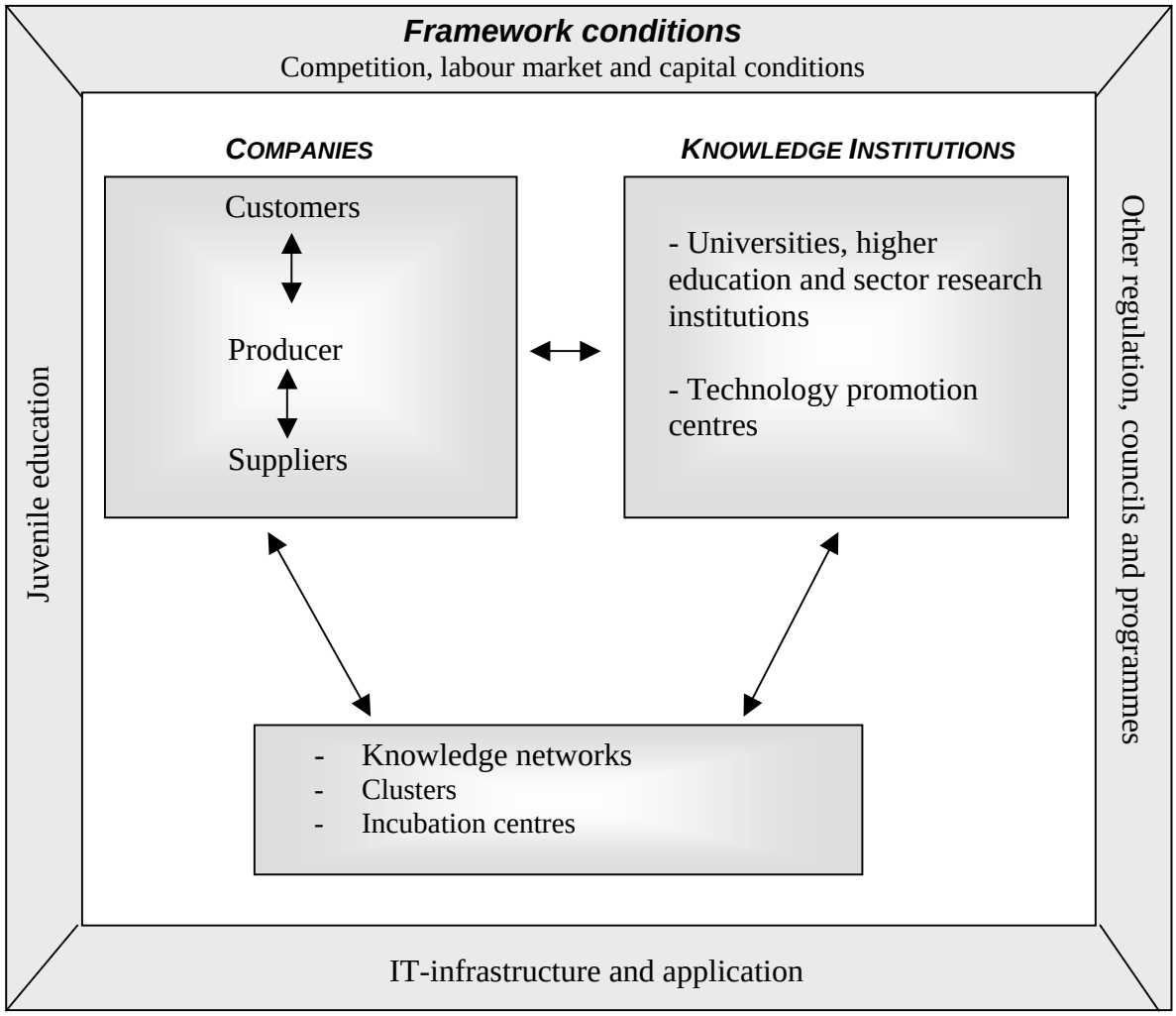
NIS research seeks to identify the distinct patterns of knowledge production and application characterizing given innovation systems. These analyses form a basis for formulating strategies for strengthening the national (or regional or sectoral) innovative capacity and competitiveness. In depth, often comparative analysis, seek on the one hand to identify the specific organization of knowledge production (the key central knowledge producers and the patterns of their interaction) on the other hand to identify the central framework conditions for the innovation process (Lundvall, 1992 eds., Freeman 1987, 1993, OECD 2000). The sum of the collected framework conditions and market conditions make up the ”selection environment” for the companies. The selection environment determines which companies and technologies survive and come to dominate the market. Hence, it is the selection environment that governs the speed and direction of technological change (Nelson and Winter, 1982).

The innovation system analysis is connected to the national level for two reasons. Partly because the nation makes up a natural level for the discussion of policy elements. Partly because a large part of the structures, values and behavioral patterns that characterize the innovation system are specific to the nation state or local regions, i.e. compare notions of “localized learning” and local specificity (Maskell, P. et al. (1998). The innovation system theory is, though, increasingly applied to other regions, such as the EU, or industrial sectors or technology areas.

NIS analyses seek to identify those distinct innovation patterns and dynamics, which characterize the different (national) innovation systems. Empirical studies show that national innovation systems vary considerably in their pattern of knowledge production and application (Nelson, 1993, Christensen et al. 1998, OECD, 1999). Despite globalizing markets and an increasing internationalization of policy regimes and, more lately, knowledge institutions.

Figure 1 seeks to illustrate the core elements of the innovation system analytical frame.

**Figure 1 The National Innovation System**




Key components in the national innovation system are the central knowledge producers in the core. On the one side companies, with emphasis on the knowledge structure of companies, i.e. the distribution of different industrial sectors and their knowledge intensity, the role of transnational companies and knowledge service. On the other side the public and semi public knowledge institutions providing research and education. Transgressing these two groups are knowledge networks, clusters and incubators that make up important spheres of cooperation between these two groups. The arrows indicate an active interplay in the knowledge production.

Surrounding the knowledge producers is the key set of institutions influencing on the innovation process. The important framework conditions are[2]:

- Competition and investment conditions.
- Labour market conditions, important for the access to skilled employees, including mobility of employees.
- Central policy conditions for innovation in general: important laws and policy instruments concerning for example intellectual property rights, the overall macro-economic conditions

[2] It varies somewhat from NIS to NIS analysis, what factors are included, depending on the purpose of the specific analysis. The mentioned elements tend to be included in many analysis at the national level, although there are often more limited analysis. Many analysis only look at more formalized research and exclude e.g analysis of knowledge networks and technological communities, restricted by the availability of R&D data as much innovation research is.

(taxation and trade policy etc.), and more specific areas such as environmental policy and agricultural policy.
- The IT-infrastructure and application facilitating rapid information sharing and coordination and
- The basic education shaping the knowledge base of society.

However, the purpose of the NIS approach is not just to shed light on these different elements, but very much to focus on their interaction and synergy effect, as the figure also seeks to illustrate. Importantly, the NIS approach makes up a system perspective in two ways: On the one hand because of its holistic approach, in including the (for companies) the surrounding institutional set-up relevant for innovation processes, which makes up large parts of society, only looked upon from an innovation perspective. On the other hand the NIS approach makes up a system perspective because of the perception of innovation as a fundamentally social and interactive process involving a wide range of actors.

The latter perspective is sometimes overlooked, leading to a misuse of the concept. There are important underlying assumptions that need to be considered when applying a NIS perspective as a basis for empirical analysis or for policy recommendations. Below the micro-theoretical conditions of the NIS approach will be looked more into.

**Underlying assumptions of the NIS perspective**

A discussion of NIS assumptions could easily involve a rather lengthy analysis of the state and various directions of evolutionary economic theory, which goes beyond this paper. Rather the intention here is to suggest four elements which seek to capture the core features of innovation systems dynamics: the role of interactive learning, the role of market institutions, the role of technological communities and the role of economic organization. The fourth element is added much as a critique of current innovation systems research, which tend to ignore these (more strategic) aspects.

*The role of interactive learning*
The innovation system perspective sees innovation as a fundamentally interactive process springing from multiple sources (Lundvall, 1985, 1988, 1992 (eds.), 2001, OECD 2000, 2001a, 2001b, 2001c). Evolutionary change is the sum of decentralized processes of discovery (Dosi, 1991). This perspective departs from the earlier linear approach to innovation, which saw innovation as the end-stage of a process driven mainly by scientific advances in basic research.

The innovation system research underlines, how the organization of knowledge production is undergoing change in the knowledge economy. The rising pace of innovation means that the innovation process is becoming even more complex. In the attempt to reach the market first with the new products, there is an increasing use of multiple knowledge sources, feedback and parallel sequences in the stages of the innovation process (OECD, 2000). This may give rise to even greater differences in the organization of knowledge production.

Three main knowledge sources for company innovation are identified; formal search and experimentation (R&D), recruitment and knowledge sharing (Lundvall, 1992). The latter refers to knowledge sharing between firms as well as between firms and knowledge institutions.

The for NIS theory central concept of *interactive learning* especially refers to the knowledge sharing between professional users and producers in the value chain (B2B). On a market a division of labour are offering opportunities for productivity gains but also needs of coordination (Hayek,

1973). The tendency for firm activities to centre around specialized knowledge or "similar capabilities" increases the coordination need on the market (Richardson, 1972). The greater the specialization and the more narrow the expertise, the greater is the likely ignorance of matters outside that expertise. Hence knowledge is distributed in the value chain among the specialized knowledge producers who need to coordinate and collaborate with each other for efficient innovation (Lundvall, 1988, 1992).[3] The point about this argument is that it sees interfirm learning as an ongoing and fundamental part of market mechanisms.

The importance of interactive learning is supported by empirical findings, which show that firms to a large extent draw their knowledge from other firms, and that their are sector specific differences in the learning patterns (e.g. Allen, 1977; Conway, 1995), Hippel, 1978, 1988; Scherer, 1982; Pavitt, 1984; Dodgson, 1993). Modern innovation system research hence relies much on analysis from the industrial cluster literature and the studies on innovation networks and interfirm cooperation (OECD 2001a, 2001b, 2001c).

*NIS and market institutions*

Closely related to the above discussion on user-producer interaction, the NIS perspective argues for a more cooperative representation of markets. Markets have fundamental problems in carrying out the identification of competent learning partners. Arm's length exchanges are insufficient in co-coordinating the innovative activities on the market (Lundvall, 1985, 1988, 1992, Casson, 1997). Firms have problems in securing co-ordinated adaptation between interrelated firms because autonomous parties read and react differently to signals. According to standard transaction cost theory such obstacles to efficient transactions and innovation lead to vertical integration (Williamson, 1975, 1985).

But the emphasis in the innovation system perspective is rather on the evolution of various forms of market institutions as firms interact on the market in order to innovate; relational assets such as trust, information channels and information codes, which remedy the inherent information problems and uncertainty related to the innovation process (Arrow, 1974, Lundvall, 1985, 1988, 1992). The presence or absence of general standards, technical as well as informational, influence on these processes (Andersen, 1999).

While many analyses emphasis the importance of trust in transaction relations the interesting element of Lundvall's (1985, 1988, 1992,1993) analysis is his emphasis on the cognitive interfirm linkages; that is, his emphasis on mediating institutions, (though not a term used by Lundvall) the information channels and codes, and how these are related to proximity issues. There is a need to develop stable interfirm relations allowing for an effectivisation and rationalization of the communication and cooperation process. A main argument is that such channels and codes are characterized by inertia. They are not only costly to establish, they also reinforce themselves as they become increasingly effective though learning, and other channels become less attractive. When the information exchange relates to technological innovations, (as assumed here), the code will be complex and specific, making changes in the channels or codes extra difficult and costly (Lundvall, 1985, Loasby 1996). Lundvall proposes from this, that the stability of user-producer relationships is a significant feature of innovation processes, influencing the directions of innovation processes. This stability is mainly gives a negative connotation emphasizing the prevalence of inertia and the occurrence of gaps between the technological opportunities and the demand (Lundvall, 1985, 1988).

[3] The NIS concept of interactive learning only relates to vertical intefirm learning. The theory fails to explain horizontal interfirm learning and why interfirm learning vary in intensity and configulation (Andersen, 1999).

A core characteristic of the NIS approach is thus the explicit focus on institution formation and transformation, noticeably the codification and standardization processes. Institutions are not only background conditioning phenomena for innovation, rather their transformation processes make up core aspects of the innovation process. Special attention is thus given here to how firms simultaneously are conditioned by, transform and create such institutions in order to innovative. In this respect the co-evolution of technology, institutions and organisations make up an essential explanation of innovation system dynamics. Markets are ”organised” rather than discrete as firms become tied together in learning relations (Lundvall, 1988, 1992).

*NIS and technological communities*
Evolutionary economic theory emphasizes the cumulative and hence path dependent and routinized manner of learning. Learning takes place within technological paradigms where attention rules and search heuristics follows patterns of problem solving activities giving rise to dominant technological trajectories (Dosi, 1982, Nelson and Winther, 1982, David, 1985).

The NIS perspective has taken on the concept of ”technological communities” or “communities of practice” (Brown & Dugiud, 1991) to capture how heuristics and learning modes become embodied between the actors who in carious ways are engaged in the same technology development, noticeably across companies and knowledge institutions. *Proximities* (geographical and cultural) between the parties will ease the creation of information codes and channels. Learning will therefore tend to take place primarily within information channels where shared codes through learning are becoming well-established (Lundvall, 1985, 1992).

This NIS approach uses this to emphasize the importance of the informal knowledge sharing and networking within the technological communities to the innovation process, which cannot be captured by R&D statistics (Lundvall, 1992, OECD, 2001a, 2001b). These networks and information channels between culturally proximate actors help to explain why regional proximity between market actors is still important for the knowledge production even in a globalizing economy.

It is equally important to consider how the technological communities within (or transgressing) the innovation system are carriers and of certain heuristics guiding the expectations (though established attention rules) and the search processes (though established search rules) (Nelson and Winther, 1982, Andersen, 1999). There is a constant competition going on between the existing and emerging technological trajectories (Dosi, 1982). The constellations and power of technological communities are important to consider when analyzing this competition. The carriers of existing technologies and knowledge in companies and knowledge institutions, ministries and other institutions tend to defend the existing trajectories emphasizing the important roles of new companies and actors from outside for the creation of more radical and systemic innovation.

*NIS and economic organisation*
While the NIS perspective argue for the co-evolution of technology institutions and *organizations*, changes in economic organization are neglected. The more recent trends in innovation theory seeks to synthesize evolutionary economic and the more strategy oriented knowledge based theory of the firm in seeking to intersect notions of economic organisation, knowledge management strategies and dynamic market processes ((Foray, 1991, Langlois, 1992, Dosi and Marengo, 1994, Teece and Pisano, 1994, Langlois and Robertson 1995, Loasby, 1996, Teece, 2000).

In contrast to the static explanations of economic organisation of the mainstream transaction cost approach these neo-institutional economic theories bring attention to the neglected costs of using

the capabilities on the market (sometimes called dynamic transaction costs, dynamic governance costs, coordination costs or information costs) (Langlois, 1992, Teece 1986, 1988, Casson, 1997). The uneven growth of knowledge on the turbulent market necessitates the transfer of capabilities between the firm and the market, depending on the respective learning capacity of the firm and the market. The costs associated with this transfer are the "dynamic transaction costs". They are the costs of accessing capabilities on the market and coordinating the divided specialised firm activities (Langlois, 1992). There are costs to engage in persuasion and teaching in order to bring the interrelated firms on a similar "wavelength" as the innovator (Langlois, 1992) and costs to building those mediating institutions which facilitate complex information exchange which sink these costs (Andersen, 1999).

In discussing economic organization emphasis is placed on the strategic choices companies have in their knowledge management. I am proposing, in accordance with Loasby (1996), that a more fluid focus on knowledge self-sufficiency may be more fruitful than the traditional market-hierarchy comparison of organizational economics (Andersen, 1999). It is central for innovation dynamics when firms decide to produce something themselves, when they buy it on the market and when they engage in knowledge sharing with other firms or knowledge institutions.

For the NIS perspective this discussion adds greater understanding of the incentives, costs and conditions for organizing knowledge production for the company, sector or nation. It is particularly important for an understanding of systemic change and the need for complementary innovations, which may expand beyond the value chain into the wider innovation system. For the innovator there are a range of strategic choices in how to "pull in" a range of different actors within the innovation system on a similar "wavelength" that will allow the innovation to succeed.

This discussion sheds more light on the discussion on match and mismatch between the different actors in the innovation system. It puts more emphasis on firm strategizing and firms as active market makers. Setting the market standard ahead of the competitors may turn into a considerable strategic advantage.

**Environmental innovation systems**

There are as stated as yet only a few examples of innovation system analysis applied to eco-innovation (see Rand Europe, 2000, Hübner et al. 2000, Hübner and Nill, 2001), so we know little about the greening of national innovation systems and the international distribution of innovative capacity on eco-innovation. Needless to say the strong role of the hitherto primarily national public intervention on environmental issues means that there are considerably national differences in the environmental innovation systems.

Applying the NIS perspective to eco-innovation is first of all important because it places eco-innovation in a broader societal context. Environmental policymaking, and much environmental research too, has tended to focus so exclusively on environmental issues that the rest of societal development has been treated as a (static) black box. Important changes in societal development and none the least competitive conditions have not been taken into consideration, leading to disoptimal policies.

The NIS perspective presents an obvious frame for discussing the consequence of the transition toward a knowledge economy for eco-innovation, a discussion that has not been picked up by environmental policy until the ETAP (EU Commission 2004). The European Commission points to the changing competitive conditions of the knowledge economy in their communication to the

Council[4] on the union's future approach to innovation policy. They argue for the need to take on a broader innovation concept and point to the following three types of innovation:

1. *Technological innovation*, primarily stemming from research.
2. *Organisational innovation* or business model innovation, related to innovative ways of organising work in areas such as workforce management, distribution, finance and manufacturing.
3. *Presentation innovation*, covering innovations in design and marketing.

The first one represents the traditional innovation perspective; the two last ones represent a new policy interest within innovation policy. They underline the decreasing role of productivity and the rising role of the more "soft" parameters for competitiveness. *Presentation innovation* relates to the rising role of branding, image and design for competitiveness, which has important implications for eco-innovation. The identity a product gives, the story associated to it, is as important as its function to many (affluent) consumers. Even in poorer economies a brand such as Coco Cola is capable of achieving rising market shares despite high costs because of its presentational value. The modern consumer wants to know a lot more about a product than its price. The political consumer is associated with this trend (Zadek, 2001).

The higher levels of knowledge in society and the rising transparency associated with the information technology revolution, none the least the internet, and the information technology revolution provides new means for telling more complex stories on companies and products. Hence a companies' image is a lot more sensitive to critique. The importance of the image/brand not the least of the very visible transnational companies, is leading to a changing role of business in society. More and more especially big companies develop strategies for corporate social responsibility (CSR)(Zadek, 2001, Zadek et al., 2003). The knowledge economy seems to offer new potential for changing into a "socially responsible economy" if we manage to support these rising but delicate trends.

While it by now is well recognized that *competition on knowledge* is central in the knowledge economy, the rising importance on *competition on values* is less recognized. But competition on values goes beyond consumerism. It is also associated with the overall need for companies to maintain a good image towards their stakeholders. Particularly the ability to attract investors and competent employees is a key competitive factor and a good image is increasingly important in both cases. Eco-efficiency and responsible behaviour could become a trademark of European companies**.**

In discussing national environmental innovation systems the point is that we need to look beyond the variations in policy regimes, albeit they are very important, and inquire further into the evolving patterns in environmental behavior and strategizing, none the least when it comes to the degree of proactivity of company behavior. The co-evolution of technology, institutions and organizations in the 30 years environmental issues have been on the international political agenda, have led to distinct patterns in the institutional set up and lock-in related to eco-innovation in various (national) innovation systems. The long period of command and control policymaking has led to *reactive* behavioural patterns among companies, but also consumers, investors and other actors in the innovation system. Realizing business opportunities is hence difficult, prohibiting more proactive environmental or CSR strategies.

[4] COM (2003) 112

The distinct formal and informal institutional setting and strategic maturity in varies countries are necessary to consider when seeking to design an innovation system which may facilitate a widespread uptake of proactive envioonmental strategic and eco-efficiency heuristics.

## 3. Policy implications – the NIS approach to sustainable development

### 3.1 NIS and policy implications

The European Commission states in their communication on innovation policy, that the innovation system perspective entails a shift in policy rationale in research and innovation policy from "*simply addressing market failures that lead to underinvestment in R&D towards one which focuses on ensuring the agents and links in the innovation system work effectively as a whole, and removing blockages in the innovation system that hinder the effective networking of its components*" (EC, 2002).

The NIS perspective may thus form the basis for RTD policy, which focuses particularly on remedying the identified system failures of the innovation system. The challenge is to create framework conditions, which lead to a selection environment that secures an ongoing high innovative capacity.

What then, are the implications of applying the NIS perspective to environmental issues? This paper argues that the NIS approach applied to eco-innovation makes up a new policy rationale departing from traditional environmental policy making in important ways. This section will seek to discuss this further.

Seen from a NIS perspective, three policy approaches are needed to create an environmental innovation system in which eco-innovation has become the "easy innovation" (Nelson and Winther, 1982). The two of the pillars are the traditional approaches in environmental policymaking, *regulation* and *fiscal measures*, which are necessary framework conditions in the environmental innovation system, but they are not sufficient for integrating environmental issues into the economic process. Rather a third policy approach is needed based on enhanced *self-regulation* facilitated by a well-funtioning national innovation system. Self-regulation is particularly important in breaking with the eco-wasteful production and consumption practices locked-in to almost all parts of the innovation system, as we shall argue further.

**Box 3.1 Three policy approaches to environmental issues**

| | |
|---|---|
| 1. Regulation | Requirements and prohibitions. Sets the legislative conditions defining companies' minimum acceptable conduct in relation to the environment. |
| 2. Fiscal measures | Taxation manipulates market pricing to internalise costs of resource use or pollution. |
| 3. Self-regulation (eco-entrepreneurship) | Wires up the innovation system to create favourable conditions for companies' voluntary eco-innovation. |

The first two policy approaches are the two traditional environmental policy instruments. Self-regulation (or possibly a better connotation is eco-entrepreneurship) through wiring up the innovation system is only emerging representing a synthesis of innovation and environmental policymaking. Self-regulation resembles and builds on the integrated product policy (IPP) of the 1990s. There are, however, important differences in the IPP and the NIS approach, as we shall return to. Below the three policy approaches are commented upon, with most emphasis on 3, which plays a central role in a NIS approach. Subsequently, the interrelationship between the three approaches are discussed

**Ad. 1 Regulation**
Environmental regulation sets the legislative conditions defining companies' minimum acceptable conduct in relation to the environment. They confine a space for the polluter within which it is acceptable to degrade the environment.

**Ad. 2 Fiscal measures**
Eco-taxes manipulate market pricing to internalise the costs of resource use or pollution. The polluter is brought to pay. Where applied they provide powerful incentives for eco-innovation.

Both regulation and taxes are important and necessary instruments for reducing environmental impact as indeed the improvements the last 30 years have shown. But they are insufficient in creating a green market economy. For once they, especially taxes, are politically delicate as they may lead to higher production costs disrupting competitiveness at least in the short run. Taxes are unlikely to gain the great extension, which are needed if they really are to make a difference. And you cannot put a tax on everything.

Even if that were the case, regulation and taxes could never on their own secure an integration of environmental issues into the economic process. Both instruments are too crude, making it impossible to provide incentives for eco-innovation for the broad business community (as well as consumers), characterized by great asymmetry in environmental response (Malaman, 1996, Erhvervsministeriet, 2000, NUTEK 2003a). I.e. addressing both the environmental laggards and the environmental leaders. Also regulation and fiscal measures are slow instruments, which need long term perspectives to work, which mean they are having problems in catching up with rapid technology development. Consequently, regulation and taxes have problems in providing incentives for continuous innovation.

Finally, regulation and taxes represent a stick approach. They both presume companies are *reactive*, and need to be forced to take on environmental action. They are not helpful in *breaking the reactive lock-in* and make companies see the environment as a business opportunity. Rather, if not properly designed, they will make companies adhere to their reactive strategies upholding dissociation to environmental issues.

**Ad. 3. Self-regulation – pursuing eco-innovation strategies**

Self-regulation, or strategies for eco-entrepreneurship, focuses on wiring up the innovation system to create competitive conditions for companies' proactive environmental activities. Whereas regulation and taxes are *hard* framework conditions that manipulate or control the market, the self-regulation approach is based on building *soft* framework conditions. The soft framework conditions *mould the market* by correcting those market imperfections associated with turbulent markets that hamper innovation, in this case eco-innovation. The soft framework conditions form the basis for

innovation policy. The key instruments are first and foremost ensuring companies' access to knowledge and capital, compare figure 1 p.6.

The point of departure in the self-regulation approach is the need to establish framework conditions that reinforce the incentives for companies to make environmental efforts themselves. For this to happen competitiveness must be made a primary driver.

In the current transition phase to a greener/more responsible market economy the market is characterized by a serious of system failures related to eco-innovation making it difficult, costly and risky to engage in eco-innovation (Andersen, 1999). There is a need to take on *a knowledge approach - to break the lock-in* into none-green understandings, technologies and routines that prevail in all parts of the innovation system. The self-regulation policy approach should aim at exactly that.

We need initiatives that aim at facilitating the creative destruction of the none-green knowledge, which lies behind current research, production and consumption patterns, and the creation of new knowledge based on principles of eco-efficiency. Building the new green knowledge is a crucial means of mobilizing and qualifying the players in the market.

The NIS approach emphasizes how it is important to build up new green knowledge widespread in the innovation system, not just in companies. Recognizing that innovation fundamentally is an interactive venture which involves a wide set of actors it is no longer enough to take initiatives directed towards single companies or sectors as much practiced in environmental policy making. The fundamental "polluter pays" principle very much reflects this approach. The NIS approach calls for a need to redefine this principle.

It is central in the NIS approach that initiatives should be made to *strengthen the coordination and learning* between the many actors involved in the innovation process. Central for the innovation process here are first of all the interdependent companies in the value chain who need to be brought on a similar "green wavelength" if the eco-innovation is to proceed smoothless (Andersen, 1999). But also the knowledge institutions, investors and consumers all need to grow new compatible green knowledge. Targeted action should be made towards *the bottlenecks* (the eco-laggards), which are currently holding back the proactive actors on the market (the eco-leaders).

Undertaking such action presupposes an analysis of the industrial dynamics of the greening process applied to the specific innovation system in order to identify the key system failures. Hereby it becomes possible to decide how most efficiently to target the action to wire up the green industrial dynamics and create self-reinforcing market mechanisms. If we are to make the market thrive, there should be a coordinated and coherent effort based on renewal and a rise in competencies in the companies' surroundings as well as in the companies themselves.

The soft framework conditions should aim to shape the market so that the market itself rewards and stimulates efforts on the part of companies to improve the environment. The goal is to create a selection environment, which will favour the survival of eco-innovations and companies with proactive CSR strategies. Customers will not select companies, technologies and service products, which are not sufficiently eco-efficient and responsible, investors and employees and gradually they will die out. In time the proactive companies will come to dominate the market and make up a new eco-efficient market standard.  and trademark.

Wiring up the innovation system for eco-innovation means making eco-innovation the *easy innovation* (Nelson and Winther, 1982). This is the case when the lock-ins have been diminished and environmental aspects are institutionalised on the market, i.e. when they form a natural part of the communication practices and tools, the technical standards and tests, the companies and knowledge institutions knowledge basis, attention and search rules and overall corporate strategizing.

### 3.2 Instruments for wiring up the innovation system for greater eco-efficiency- a three pillar strategy for greening the innovation system

In the following some policy implications of the NIS approach will be sought identified and a few key policy initiatives are suggested that may in important ways break the current reactive lock-in and lead to a kick-start of the green market development. The intention is not to undertake a detailed discussion of policy instruments but rather to point to some new considerations the NIS rationale may add to existing environmental policy practices.

This paper suggests that a strategy for moulding the market for eco-innovation should aim on the following three pillars:

Table 3.1 A three pillar strategy for the greening of the innovation system

| **Policy areas** | **Targets** | **Possible action themes** |
|---|---|---|
| Policy area 1 | | |
| Well-functioning green markets | The environment as a natural criterion in all purchase and sales situations throughout the value chains nationally and internationally. | -Qualifying the green demand. |
| Policy area 2 | | |
| Green organizational development | The environment as an integrated part of companies' competitive strategies and day-to-day decisions. | -Promote market-oriented environmental strategizing and management. |
| Policy area 3 | | |
| Green technology development | Building strong environmental competencies in companies and knowledge institutions for a high overall innovative capacity on eco-innovation. | -Promote a forward-looking and coordinated green R&D effort. |

Ad. Policy area 1 focuses on the demand side and seeks to build a well-functioning competition on environmental parameters. Eco-labels, as promoted by IPP, have been successful in obtaining a beginning greening of the economy, but they cannot lead to a real kick-off of a green market economy. The bulk of consumers lack the knowledge to decode the eco-labels that have limited

information value. Rather we need to find new ways to tell the "stories" behind the products, stories that will allow knowledge to be build on the causal relation between a product or activity and its environmental impact. Such knowledge is much more difficult to displace. The information technology revolution offers new opportunities for developing smart ways for this more complex market communication, none the least the internet, which should be fully explored. But also the basic environmental education in schools should shift towards a more product-oriented approach. A challenge, but also an opportunity, to be addressed is the expansion from mere environmental communication towards the broader ethical agenda of the CSR strategizing.

Ad. Policy area 2 focuses on empowering the key organizations in the innovation system towards proactive environmental and responsible behavior. First of all companies who are the key solution to sustainability. Widespread proactive CSR strategies among the bulk of companies are a key milestone to eco-innovation. There is a substantial need for management, organizational and competence renewal to change the current (reactive) mindset, organizational set up and management tools aimed at environmental regulation.

Environmental management systems should be changed from a technical exercise carried out by technicians into eco-efficiency management philosophy to form a part of the overall competitive strategy of companies. This is necessary for companies to become active market markers on eco-innovation. The internal organization matters, i.e. the location and position of companies' environmental and ethical work affect the influence this work gains. There is among other things a need to build new eco-technical competencies in the sales and marketing departments to deal with the new complex environmental communication towards customers (Andersen, 1999).

The reactive stance amongst many companies should be taken seriously. Companies generally do not think strategically about environmental issues. They only consider whether they live up to environmental regulation or not. They do not know neither the costs nor the various benefits related to their environmental activities and routinely see eco-innovation as a burden rather than an opportunity (Erhvervsministeriet, 2000). Their attention rules need to be changed by new reporting measures (triple bottom line) and by various means of demonstrating the potential profitability related to eco-innovation.

The green organizational development area ties together the demand side (policy area 1) and the technology push side (policy area 3). Action on organizational development should be targeted towards key actors in the greening of the innovation system. The leaders pushing the green market development should be supported and the bottlenecks (the laggards) should be mobilized. E.g. currently noticeably the retailers and whole salers (so important for policy area 1) and investors (important for policy area 3). The uneven distribution of incentives and resources on the market should be taken into account in developing a differentiated approach and a step model for the distribution of proactive CSR. It is necessary for a green market development, however, to aim at all companies so as to achieve a similar "green" wavelengths and complementary adaptation of eco-efficiency strategies in the business community.

Governments should provide consistent and ongoing strong incentives for the development of proactive environmental and responsible issues in company strategies. Rewards, demonstration (of business opportunities), accounting, indicators and benchmarking are important instruments.

Ad. Policy area 3 seeks to strengthen the green technology push. Widespread environmental competencies and knowledge sharing in and between business and knowledge institutions, strong

clusters on core environmental competencies, dynamic incubator environments and good access to capital are key features for a high innovative capacity for eco-innovations.

Targeted policies for eco-innovation should focus and position the innovation system towards key strategic areas. But at the same time it should be realized that all environmental competencies are important as they feed into a common knowledge base. E.g. the companies developing the (scolded) add-on technologies are also involved in cleaner technology development, and for most companies the development of integrated and add-on technological solutions is closely related. A strong environmental sector is important for building an overall high innovative capacity on eco-innovation.

The common denominator for the three policy initiaitves mentioned here is the strong focus on knowledge. The mentioned policy areas are closely intertwined and presuppose each other. A key point of the NIS approach is that policy measures need to be introduced in a well-coordinated and timely way. It matters when and in what order which actors or elements within the innovation system are mobilised for the green industrial dynamics to function.

These policy measures should aim to create more cohesion and better coordination in the very asymmetric national and international (e.g. EU) environmental innovation systems, by focusing on removing bottlenecks and furthering interactive learning and coordination among the many interdependent players in the innovation system.

### 3.3 Balancing regulation, fiscal measures and self-regulation

Ideally, good soft framework conditions would in the long term make the market the driving force for a green/responsible market development. However, in the current stage all three policy approaches are needed for furthering a transition to a green market economy. More attention should be made to the interplay and the trade-off between the three types of instruments. It matters how they are used (the relative mix). If company self-regulation is to play a major role, regulation and eco-taxation must provide incentives for this.

*Rewarding the companies with proactive CSR-strategies should be a core principle* behind all policy approaches**.** An innovation friendly environmental policy must be based on an extended partnership between companies and government. Such policies must be very dynamic and differentiated to provide continuous incentives for proactivity for both the environmental leaders and the environmental laggards. There may be a trade-off and certainly a need for finding a new balance between regulation and self-regulation.

## 4. Conclusion

The NIS perspective, this paper has argued, makes up a new rationale in environmental policymaking, the possible implications of which yet need to be further explored and tried out. At first the NIS approach seems to resemble the IPP (integrated product policy) as promoted by environmental policy in later years. But while both seek to promote company voluntary environmental action, there are at least two important differences, reflecting differences in the underlying assumptions and perception of the industrial dynamics involved: 1) The goals, notably the treatment of competitiveness. And 2) the delimitation of the system or actors involved.

**The goals**
The IPP takes a point of departure in the environment. Focus is on achieving environmental impacts on key environmental issues by providing companies with tools to integrate environmental issues in their activities. The NIS approach applied to eco-innovation, on the other hand, takes a point of departure in company strategizing and green competitiveness. Focus is on the long-term goal of building up a knowledge and capital infrastructure aiming at a high innovative capacity on environmental issues at the national or regional level. Actions are taken to strengthen the green industrial dynamics and wire up the innovation system for eco-innovation. This means that action is targeted at the system failures related to eco-innovation rather than at specific environmental goals as such.

Applying the NIS approach points to the possible trade-off between aiming at (urgent) environmental goals and aiming at building up a (long term) high green innovative capacity. The trade-off should be realized when seeking to make eco-innovation a means for synthesizing environmental and innovation policy. The relationship between enhancing competitiveness and reducing environmental degradation should be clarified further. This trade-off is not clearly addressed in e.g. the ETAP action plan.

The NIS approach argues that for the green market economy to take off, green competitiveness must become a primary goal and driver for business. We need innovation policy and not only environmental policy to further eco-innovation. The ETAP is an important step in that direction. Given the major system failures related to the current early phases of the transition towards a greener market economy there is much need for innovation system policy which can identify and rectify those system failures and help companies in the move towards proactive CSR strategies.

**The system perspective**
The IPP takes a product perspective. The focus is on the environmental effects of product innovations in the product chain going from cradle to grave (the life cycle perspective) and the according need to integrate environmental issues in the entire product chain. However, there is not much focus on the need for coordinated product innovations. The NIS perspective is more comprehensive, looking at innovations (mainly technological but also services) and not only products, and with a strong focus on the coordination needs and interactive learning related to these (to varies degrees systemic) innovations. Emphasis is furthermore put on the underlying organization of knowledge production, i.e. the interfirm learning relations and interdependencies, which are both vertical and horizontal and may stretch far out into the innovation system (the technological community) going much beyond the “product chain”. Further more, the NIS perspective takes into consideration the wider institutional set up, e.g. capital and labour conditions, intellectual property rights ect. that influence on the innovation process.

There are also some considerations to make in applying the NIS approach to environmental issues. There tends to be quite a strong focus on technology push perspectives, while market development perspectives are neglected (Andersen, 1999). The NIS perspective forwarded in this paper has sought to overcome this issue by arguing for the simultaneous focus on building well-functioning markets, organizational development and coordinated technology development.

Thus the NIS approach points to the need to rethink the interdependencies and the incentive structures related to eco-innovation. IPP, with its promotion of eco-labels, environmental management systems and cleaner technology programs, has been successful in obtaining a beginning greening of the economy, but there has been no real kick-off of a green market economy.

A lacking focus on green competitiveness, institutional lock-in and insight into innovation dynamics has inhibited a strategy for wiring up the innovation system for eco-innovations.

The differences in perspective pointed to have a major influence on the policy programmes undertaken. We need policy programmes with much stronger focus on knowledge, both when it comes to pulling the demand, pushing technology and making companies' strategic market makers on eco-innovation.

The NIS perspective is also important because it can:

- help to create a vision – which ETAP lacks - on where we need to go. A vision of a green innovation system where eco-innovation has become the easy innovation and an important trademark.

- place eco-innovation witin the wider context of the knowledge economy and the changing competitive conditions it represents, including the new opportunities presented by the rise of presentation innovation and CSR.

- put emphasis on the distinct features of different national environmental innovation systems, and hence the specific conditions for eco-innovation which none the least can aid the transfer of experiences and policy measures between countries, e.g. towards the new EU countries.

Applying the NIS perspective to eco-innovation in many ways presents a challenge to NIS theory and innovation policy (Andersen, 1999). Innovation research and policy has so far to a wide extend managed to ignore the wider societal consequences of innovation. A focus on environmental innovation systems may help remedy this. Just as environmental strategizing in companies has paved the way towards the wider corporate social responsibility strategizing.

The NIS approach is only emerging in the environmental field, but it carries promising perspectives for a renewal of environmental policy. We need though, empirical studies on environmental innovation systems and the development of relevant indicators to benchmark these.

It is time not only to talk about integrating environmental issues into other policy domains but of opening the plack box of environmental policy and placing environmental issues within a wider societal agenda. If we manage that, eco-innovation and CSR may become an important agenda in the knowledge economy, for the good of competitiveness as well as the environment.

**References**

Andersen, M. M. (1999) *Trajectory Change through Interorganisational Learning. On the Economic Organisation of the Greening of Industry,* Ph.d. dissertation, The Copenhagen Business School Ph.D. series 8.99, Copenhagen.
Andersen, M. M. (2002): "Organising Interfirm Learning – as the Market Begins to Turn Green", in de Bruijn, T.J.N.M. and A. Tukker (eds.), Partnership and Leadership – Building Alliances for a Sustainable Future. Dordrecht: Kluwer Academic Publishers, pp.103-119.
Brown,J.and P. Duguid (1991), "Organisational Learning and Communities of Practice", *Organization Science,* 2, pp.40-57.

Casson, M. (1997) Information and Organization. A New Perspective on the Theory of the Firm. Oxford: Clarendon Press.
Charter, M. and Clark, T. (2002) *Sustainable Value, Greenleaf Publishing, UK: Sheffield.*
Cohen, W.M. and D.A. Levinthal (1990). "Absorptive Capacity: A new Perspective on Learning and Innovation", *Administrative Science Quarterly*, **35**, pp.128-152.
Coombs, R. et al. (eds.) (1996). *Technological Collaboration - The Dynamics of Cooperation in Industrial Innovation*, Cheltenham: Edward Elgar.
David, P.A. (1985). "Clio and the Economics of Qwerty", *American Economic Review*, **75**(2), pp.332-337.
David, P. A. (1987). "Some New Standards for the Economics of Standardization in the Information Age", in Dasgupta and Stoneman (eds.), *Economic Policy and Technological Performance*, Cambridge: Cambridge University Press, pp.206-239.
Dosi, G. (1982). "Technological Paradigms and Technological Trajectories: A Suggested Interpretation of the Determinants and Directions of Technological Change", *Research Policy*, **11**, pp.147-162.
Dosi, G. et al. (eds.) (1988). *Technical Change and Economic Theory*, London: Pinter Publishers.
Dosi, G. and L. Marengo (1994). "Some Elements of an Evolutionary Theory of Organizational Competences", in R.W.England (ed.), *Evolutionary Concepts in Contemporary Economics*, Michigan University Press, pp.157-178.
Foray, D. (1991). "The Secrets of Industry are in the Air: Industrial Cooperation and the Organizational Dynamics of the Innovative Firm", *Research Policy*, **20**, pp.393-405.
Euripean Commission (2002), *Report on Research and Development*, EC Economic Policy Committee Working group on R&D, EPC/ECFIN/01/777-EN Final, Brussels, January 2002.
European Commission (2003): *Developing an Action Plan for Environmental Technology*. Website http://europa.eu.int/comm/environment/etap
Edquist, C (2001), "Innovation policy – a systemic approach". In The Globalizing Learning Economy, Archibugi, D and Lundvall, B. (eds.), Oxford University Press.
Ecotec (2002) Analysis of the EU Eco industries, their employment and export potential, report for DG Environment of the European Commission. ECOTEC Research & Consulting Limited.
Erhvervsministeriet (2000), *Virksomheders Miljøadfærd, kortlægning og analyse*, Copenhagen.
ESTO (2000a). *Eco-design; European state of the art - Part I: Comparative analysis and conclusions*, by Tukker, A., Haag, E., Eder, P. ESTO project report, EUR 19583 EN, Joint Research Centre Seville, EUR 19583 EN.
Tukker, A., Eder, P., ESTO project report, Joint Research Centre Seville.
Foray, D. (1991). "The Secrets of Industry are in the Air: Industrial Cooperation and the Organizational Dynamics of the Innovative Firm", *Research Policy*, **20**, pp.393-405.
Freeman, C (1988), Japan: a new national system of innovation? In Dosi et al. (1988), Technical Change and Economic Theory, Pinter Publishers, London.
Freeman, C. (1995). "The ´National System of Innovation` in Historical Perspective", *Cambridge Journal of Economics*, **19**, pp.5-24.
Freeman, C. (1992) *The Economics of Hope*, Pinter Publishers.
Grant, R. M. (1991). "The Resource-Based Theory of Competitive Advantage: Implications for Strategy Formulation", *California Management Review*, Spring, pp.119-135.
Hübner, K., et al. (2000), *"Greening of the Innovation System? Opportunities and Obstacles for a Path Change towards Sustainability: The Case of Germany"*, Working paper 47/00, Institute for Ecological Economy Research, Berlin.
ICCEPT (2003), *The UK innovation Systems for New and Renewable Energy Technologies*, report to DTI, Imperial College London, London
Kemp, R. (2002), Synthesis Report of 1st Blueprint Workshop on „Environmental Innovation Systems". Brussels, www.blueprint-network.net

Kemp, R., J. Rotmans (2001). The Management of the Co-Evoultion of Technical, Environmental and Social Systems. Paper for the international conference "Towards Environmental Innovation Systems", September 27 – 29, Garmisch-Partenkirchen
Langlois, R.N. (1988). "Economic Change and the Boundaries of the Firm", *Journal of Institutional and Theoretical Economics*, **144**, pp.635-657.
Langlois, R.N. (1992). "Transaction Cost Economics in Real Time", *Industrial and Corporate Change*, **1**, pp.99-127.
Langlois, R.N. and P.L.Robertson (1995). *Firms, Markets and Economic Change. A Dynamic Theory of Business Institutions*, London: Routledge.
Loasby, B. (1996). "The Organisation of Industry", in J. N. Foss & C. Knudsen, *Towards a Competence Theory of the Firm*, London: Routledge, pp.38-53.
Lundvall, B. (1985). *Product Innovation and User-Producer Interaction*, Ålborg: Ålborg Universitetsforlag.
Lundvall, B. (1988), "Innovation as an interactive process: from user-producer interaction to the national system of innovation". In Dosi, G et al. (1988), Technical Change and Economic Theory, Pinter Publishers, London.
Lundvall, B. (ed.) (1992). *National Systems of Innovation*, London: Pinters Publishers.
Malaman,Roberto (1996). Technological innovation for Sustainable Development: Generation and Diffusion of Industrial Cleaner Technologies, Fondazione Eni Enrico Mattei
Maskell, P. et al. (1998). *Competitiveness, Localised Learning and Regional Development: Specialization and Prosperity in Small Open Economies*, London: Routledge.
Nelson, R.R. and S. Winter (1982). *An Evolutionary Theory of Economic Change*, Cambrige, MA: Harvard University Press.
Nelson, R (1993), *National Systems of Innovation: A comparative analysis*, Oxford University Press, New York
NUTEK (2003a). *Miljöarbete i småföretag – en ren vinst*, NUTEK, B 2003:2.
NUTEK (2003b). *Nationell kraftsamling för miljödriven näringslivsutveckling – ett förslag til strategi*, NUTEK.
OECD (1999), *Managing National Innovation Systems*. OECD, Paris
OECD (2000), *Knowledge management in the Learning Society*. OECD, Paris
OECD (2001a), *Innovative Clusters. Drivers of National Innovation Systems*. OECD, Paris.
OECD (2001b), *Innovative Networks. Cooperation in National Innovation Systems*. OECD, Paris.
OECD (2001c), *Cities and Regions in the New Learning Economy*. OECD, Paris.
OECD (2002), *Dynamising National Innovation Systems, OECD*, Paris
Pavitt, K. (1984). "Patterns of Technical Change: Towards a Taxonomy and a Theory, *Research Policy*, **13**(6), pp.343-373.
Penrose, E.G. (1959). *The theory of the Growth of the Firm*, New York: Wiley,.
Rand Europe (2000), *"Stimulating industrial innovation for sustainability: An international Analysis"*,. Report for the Dutch Ministry of Housing, Spatial Planning and the Environment, Leiden.
Rand Europe (2000), *"Stimulating industrial innovation for sustainability: An international Analysis"*, nine country reports, Leiden.
Rennings, K. et al. (2004) Blueprints for an Integration of Science, Technology and Environmental Policy.
Richardson, G.B. (1972). "The Organisation of Industry", *The economic Journal*, **82**, pp.883-896.
Smith, K. (2002), Environmental Innovation in a Systems Framework. Paper presented on the 1st Blueprint Workshop "Environmental Innovation Systems", Brussels, January 2002, www.blueprint-network.net
Teece, D. (1986). "Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy", *Research Policy*, **15**, pp.27-44.

Teece, D. (1988). "Technological Change and the Nature of the Firm", in Dosi *et al.* (eds), pp.256-281.
Teece, D. (1989). " Economies of Scope and the Scope of the Enterprise", *Journal of Economic Behaviour and Organization*, **1,** pp.223-247.
Teece D. (2000) "Strategies for Managing Knowledge Assets: The Role of Firm Structure and Industrial Context", Long Range Planning 33, pp. 35-45.
Teece, D. and G. Pisano (1994). "The Dynamic Capabilites of Firms: An Introduction", Industrial and Corporate Change, **3**(3), pp.537-556.
Weber, M and J. Hemmelskamp (eds.) *Towards Environmental Innovation Systems*, forthcoming, Springer Verlag.
Zadek, S. (2001) *The Civil Corporation: the New Economy of Corporate Citizenship*, London: Earthscan.
Zadek, S., Sabapathy, J., Døssing, H., and T.Swift (2003) *Responsible Competitiveness. Corporate Responsibility Clusters in Action*, Copenhagen: The Copenhagen Centre and Accountability.