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Eco-innovation in the Globalizing Learning Economy:

The Greening of National Innovation Systems

Name of Corresponding Author	Maj Munch Andersen
Title & Position	Senior scientist
Institution & Full Postal Address	Department of Management, Technical University of Denmark, Lyngby, Denmark
E-mail Address	mmua@man.dtu.dk

Abstract

The latter years the relationship between the environmental agenda and the economy has undergone dramatic change shifting from being seen as a barrier to economic growth to increasingly being seen as a core driver of global economic development. There is currently an intensive search for new international and national policies to address this new agenda.

This paper seeks to forward a new innovation-friendly policy environmental rationale based on evolutionary economic theory, a perspective that hitherto has only been little applied to the environmental area. The paper posits that the global economy is in a process of green economic evolution that should be seen in relationship with the rise of the learning economy and which leads to a 'green learning economy', a process that will entail substantial creative destruction and creative accumulation around the globe. The paper suggests that taken the time and space dependencies of the economic process seriously, the "national innovation system" theory offers a suitable framework for a more innovation oriented rationale for addressing environmental issues globally. The paper outlines core features and visions for a greening of national innovation systems of relevance for developed as well as developing economies.

Keywords: Eco-innovation, national innovation systems, innovation policy, climate change mitigation policy, evolutionary economic theory, economic development

1. Introduction

The last few years the environmental agenda has undergone a dramatic transition in scope and orientation. The environmental area, none the least climate change, is increasingly recognized as a main global problem by both developed and developing countries. But the main change lies in the shift from viewing the environmental agenda as a burden to economic growth to increasingly viewing it as an important driver of global economic development. There is currently an intensive search for new international and national policies to address this new agenda in both developed and developing countries.

This paper seeks to forward a more innovation-friendly policy rationale based on evolutionary economic theory, a perspective that hitherto has only been little applied to the environmental area. The paper takes as a starting point that the global economy is in a process of green economic evolution towards a 'green learning economy', a process that will lead to major structural changes and affect all economies around the globe. The paper posits that taken the time and space dependencies of the economic process seriously, the "national innovation system" theory offers a suitable framework for a more innovation oriented rationale for environmental and climate policies. The paper suggests that both developed as well as developing countries may advantageously address this new agenda by aiming for a greening of their national innovation systems. The paper outlines core features and visions for such a greening of national innovation systems.

1.1 The background

The end zeroes have seen a rapid increase in policy as well as business attention to environmental problems, none the least climate change, so far peaking at the UN COP15 climate mitigation world top meeting the end of 2009. Though expectations of reaching new global carbon reduction targets were not met, the attention remains high globally so far. The environmental policy area has through this process gained a much more central position than before. While the warnings on human-induced climate

change have strengthened (IPCC, 2008), this seems only part of the reason for the rising climate interest. Rather the alignment of environmental issues with energy supply targets and security policies has created a very powerful political agenda which has gained a dramatically rapid widespread acceptance internationally, but even more importantly also across policy domains (Andersen, 2009; Andersen and Foxon, 2009). The effect has been significant particularly in the innovation policy area where "green growth" and "green recovery" have suddenly become mainstream core global policy goals. There seems to be a new global race to become leaders in what leading politicians term the "New green deal" (Obama, 2009; Brown, 2009) or "the green industrial revolution" (Milliband, 2007; Barroso, 2007).

These developments represent a marked changed from earlier policy practice. The environment has largely been seen as a cost to business and therefore as something innovation policy should seek to restrict (Kemp and Andersen, 2004, Andersen, 2008a). Preceeding the recent climate era, there has, however, been a slow rise of the "eco-innovation" agenda starting around the turn of the millennium. Analytically, the eco-innovation concept unifies environmental and economic goals in emphasising green competitiveness as a core driver for environmental improvement; in relation to policy, it seeks to forward greater synergy between environmental and innovation policy (see e.g. Fussler and James 1996; Andersen, 1999, 2004b, 2006, 2008a 2008, 2009; Andersen and Foxon, 2009, 2010a. 2010b; Fukasako 1999, WBCSD 2000, Rennings 2000, 2003, Markusson, 2001, OECD 2005, 2009; Foxon 2005, van den Bergh et al., 2006, 2007; Reid and Miedzinski, 2008). Eco-innovation policy represents a very immature policy area in need of further clarification and indicators but it is gaining rapid momentum these last 1-3 years, none the least at the level of international institutions such as EU, OECD and UN (EUROPEAN COMMISSION 2003, Kemp and Andersen, 2004; COM 2006, UNESCAP, 2007, OECD 2009).

Current environmental and climate policies offer limited aid for this new agenda. Their foundation in neoclassical economic understandings offers a too limited emphasis on innovation but also a too linear thinking on innovation and a neglect of learning which is related to the neoclassical economic thinking lying behind. The traditional assumption of the environment as a given negative externality and an economic burden has meant that the greening of markets has not been recognized and

addressed. The focus on short run allocation issues and the assumption of rational actors and efficient markets are ill fitted to address long run environmental problems associated with major uncertainties. More specifically the assumption that causality runs from science to technological innovation has led to a belief that simply investing more in low-carbon R&D will bring about efficient eco- innovation. Little attention is currently placed on the specific dynamics and system failures for eco-innovation in different given innovation systems. Especially developing countries have received little attention from an innovation perspective. There has been a lack of positive economic goals and visions which could guide the transformation from the current high-carbon, resource inefficient economy to a low-carbon resource efficient economy (Andersen, 2009; Andersen and Foxon, 2009).

This paper seeks to forward a more innovation-friendly policy rationale based on evolutionary economic theory, a perspective that hitherto has only been little applied to the environmental area. Fundamentally, this rationale represents a shift in attention from regulation to learning. The paper takes as a starting point that the global economy is in a process of green economic evolution leading towards a 'green learning economy'. This process will entail major structural change of the economy and affect all economies around the globe. The paper posits that the green economic evolution form parts of and could not take place without the changing competitive requirements of the globalizing learning economy. We may interpret the rise of the green learning economy as a shift from a resource intensive towards a knowledge intensive economy. The paper argues further, that green economic evolution may be characterized as an unusual uneven economic process both at the national level and the firm level. In a global perspective, national economies are at very divergent stages on the green learning curve. There is therefore a strong need for targeted and localised solutions as well as coordinated action. There is none the least a need to reconsider policies in a developing countries context.

The paper posits that taken the time and space dependencies of the economic process seriously, the "national innovation system" theory offers a suitable framework for a more innovation oriented rationale for environmental and climate policies. The paper suggests that both developed as well as developing countries may advantageously address the new green agenda by aiming for a greening of their national innovation

systems. The paper outlines core features and visions/targets for such *a greening of national innovation* systems.

I posit that a national innovation system is green when it upholds a high eco-innovative capacity as compared to other economies, i.e. it is a relative measure. The emphasis is on the innovative capacity at the aggregate national level rather than the environmental performance of the economy per sé. This is the important novelty of the innovation system approach as opposed to more traditional economic or environmental approaches. A more absolute measure, but still with an innovation focus, is that eco-innovation has become the 'natural' innovation in the economy (Nelson and Winters seminal term (1982)) where innovation and technology routinely moves in a green direction. When these goals are met not only at national levels but at the global level, we may refer to the 'green learning economy'. Obviously, the global economy is currently far from having reached such a green stage. The important point here is though that everything indicates that the economy is moving in such a green direction and will continue to do so as I shall argue further below.

Four core policy targets for achieving a greening of national innovation systems are suggested:

1. a selection environment that favours eco-innovation
2. an efficient organisation of green production and learning across firms and knowledge institutions in the innovation system
3. a strong green knowledge base
4. the creative destruction of institutions and technical infrastructures which hamper eco-innovation and the creative accumulation of new greener ones.

These targets are relevant for both developed and developing economies. The paper argues that greening the national innovation system is an important element in meeting the changing competitive requirements of the globalizing learning economy. I shall expand on these claims further below

The paper is structured as follows. Section 2 discusses shortly eco-innovation and green economic evolution. Section 3 outlines innovation systems thinking. Section 4 examines the greening of innovation systems. Section 5 concludes.

2. Eco-innovation in the learning economy

This section offers shortly a definition of eco-innovation from an evolutionary economic perspective and relates this to the concept of the learning economy.

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2.1 Understanding eco-innovation

Fundamentally "eco-technologies", now superseded by the concept of "eco-innovations", are technologies or services which remedy environmental problems. There have been many different concepts in use over time to a large degree reflecting changes in environmental policy focus. With a still more preventive and integrated policy approach to environmental issues the focus has changed from environmental technologies/End-of Pipe to cleaner production processes, cleaner products to the broader eco-innovation or, also widely used, clean-tech concept. Lately, low-carbon or climate technologies are added to the list of common concepts. Fundamentally, understanding eco-innovation entails understanding the changing relationship between society and nature over time and the attempts to develop novel solutions to deal with man-made environmental degradation. The paper will not go into a very detailed discussion of specific taxonomies of eco-innovation categories (see Andersen, 2006). For the point of the more fundamental discussion on eco-innovation dynamics and the greening of markets in this paper, we will stick to two main eco-innovation categories:

A. Pollution- and resource handling technologies and services.
B. All technologies, products and services, which are more environmentally benign than their relevant alternatives

These two main categories are well consolidated and in accordance with the EU definition of environmental technologies (EU Com, 2004). From these two eco-innovation categories it is apparent that eco-innovation is difficult to define and address, both because of the complexity but even more the relativity of the subject. This goes particularly for the category B eco-innovations which are a lot more complex and fluid. Greening is a moving target; innovations which are considered green today may be outrun by greener alternatives at some point (Andersen and Kemp 2004, Andersen, 2006, 2008b; Kemp and Pearson, 2007). Existing statistics mainly

cover the category A eco-innovations (pollution- and resource handling technologies and services), while category B, the innovations which are greener than the alternatives, are more or less left out. Statistics and indicators are still poor (see Kemp and Arundel, 1998; Kuhndt et al., 2002a, 2002b, Arundel, Kemp and Parto 2004, Horbach (ed.) 2005, Andersen, 2007, Kemp and Pearson, 2007, OECD, 2009a, 2009b.)

While eco-innovation hitherto has been defined in technical terms, also by evolutionary economists (Kemp and Arundel, 1998; Kemp and Pearson, 2007) focusing on the degree and type of environmental impacts the technologies remedy, it is here suggested to define eco-innovation in economic terms. *Eco-innovations are innovations which are able to attract green rents on the market* (see also Andersen, 1999, 2002, 2006, 2008a, 2008b, 2010). They are innovations which (appear to) reduce net environmental impacts while creating value on the market. Following this definition the eco-innovation concept is inherently linked to green competitiveness and green economic evolution. It is not decisive how green an innovation is but to what degree the environmental parameter has become a selection parameter on the market. Eco-innovation then is a measure of *the degree to which environmental issues are becoming integrated into the economic process.* Following this definition the concept intersects environmental degradation with innovation and economic performance. The eco-innovation concept signals that the environment is becoming significant for the economic process.

Issues of the role of negative externalities, including environmental degradation, for economic evolution have only been dealt with very limited from an evolutionary economic perspective. The externality problems, including environmental externalities, are treated as dynamic (Kemp and Soete, 1992). The phenomena to which the “externality” tag is applied are not given but are related to particular historical and institutional contexts rather than definitive once-and-for-all categorizations (Nelson and Winter ,1982). However, this discussion does not address how the selection properties might change and hence internalize the externalities in the economic process as captured by the suggested eco-innovation concept.

The eco-innovation concept is broad, as eco-innovations may, as other innovations according to the OSLO manual, be technical, organizational or marketing innovations as long as they improve the "green competitiveness" of a company (Kemp and Andersen 2004, Andersen, 2006, 2008b). [1] There are basically two ways a firm may attract green rents on the market: Either by acquiring a premium price for its green reputation or product, or to reduce production costs by achieving greater resource efficiency or reducing the costs of costly emission treatment.

2.2 Towards the green learning economy

The knowledge economy, or learning economy, is characterized by an intensified global competition. Competition on knowledge and the ability to learn is increasingly important meaning that intellectual capital is becoming relatively more important than production capital. Rapid cheap and massive communication in and outside the market via ICT is an important feature facilitating innovation and learning in this economy. In such an economy it becomes increasingly important for firms to compete on other features than costs, particularly for the more developed economies with high labour costs (OECD, 2000, 2003; Lundvall, 2007). Increasingly also social capital is recognized as an important feature supporting the creation of intellectual capital (Lundvall, 2007). Natural capital has hitherto been given very little attention and more as something that it is important to preserve for social reasons than for economic reasons (Lundvall, 2007). I argue that natural capital is as important as social capital as a basis for economic development. Both at the macro aggregate level of national, regional and global economies as well as the micro firm level. At the macro level a healthy natural capital allows for a smooth economic development averting risks and uncertainties related to possible costs of pollution abatement, costs which may become astronomically large if for example climate change or other natural disasters takes up speed. At the micro firm level eco-innovation is increasingly becoming an interesting profit opportunity as a green profile of a product or a company increasingly is recognized as (necessary) quality parameter, particularly making high costs products attractive.

[1] The concept is related to the wider "sustainable consumption and production" concept (SCP), though the two concept areas have been little linked so far (see though Andersen, 2008, Tucker et al. 2008).

The changing competitive conditions of the learning economy should therefore be seen as a prerequisite for the ongoing green economic evolution. However, the linkage between the learning economy and the greening of the economic process goes further. I posit that the green economic evolution requires an extraordinary high degree of knowledge and learning. The argumentation is two-fold: Partly at the level of selection, partly at the fundamental cognitive level. At the level of selection it is important to recognize that the rise of the green market is associated with unusually high information and knowledge needs. This is because of some specificities of eco-innovations. The environmental parameters are credence characteristics and hence require some kind of communication standards for their documentation(eg. eco-labels, environmental product declarations, certified environmental management systems and CSR ect.). The complexity (many environmental parameters to consider), systemic and global environmental assesment (the environmental performance of a given product is assessed on the bases of global value chains, the recycling aspects goes beyond the single firm), and in many cases relativity (greener than the alternatives at a given time) of the environmental assessment of a given product and company adds to the high information and knowledge needs among users. However, with green economic evolution the market comes to function increasingly effective as a selective device on environmental parameters; mediating green institutions and standards are created and the dynamic transaction costs to eco-innovation are lowered significantly (Andersen, 1999, 2010b). This also means that the green economic evolution has a stronger globalization aspects than is often recognized. It is none the least forwarded by the mentioned global environmental assessment practice (the environmental performance of all actors in the global value chains are routinely taken into consideration in environmental assessments to be included in standardized eco-labels or environmental management systems, meaning that the greener companies (often in the developed economies) are setting green demands on their suppliers and occasionally users. These green formal mediating institutions, as well as the formation of informal green communication practices and green knowledge among users are formed as part of the globalizing economic process and are essential in creating well-functioning green markets (Andersen, 1999).

The costs of creating these institutions have to a large degree been born by the early moving developed economies (which is fair as these have also to a very high degree caused the global environmental problems). The sunk costs to greening means that it

is becoming easier for the late coming economies to enter the green market, where green market supporting institutions are more in place and the friction to eco-innovation generally is lower. Still, it is important to recognize that the rise of environmental issues as a selection parameter on the market necessarily will be associated with very high information and knowledge needs.

Concerning the fundamental cognitive level I forward a strong paradigmatic explanation of green economic evolution based particularly on Dosi's work on technological paradigms and trajectories which emphases the cognitive aspects of paradigm retention and change (Dosi, 1982).[2] Many researchers, also some evolutionary economists, have pointed to the need for a green techno-economic paradigm change. The argument is that only radical fundamental change of production and consumption patterns will entail sufficient rise in the global resource efficiency to allow an environmentally sustainable development in the long run (Summerer 1989; Kemp and Soete 1990; Kemp, 1994; 1996; Gladwin 1993; Freeman 1992). Lately there is much reference in the climate debate of the shift from a high- to a low-carbon economy as a paradigm change but little in-depth discussion of this (Unruh, 2000, 2002). However, these discussions have not really analyzed whether the green economic change is of such a scope and durability as to be characterized as a techno-economic paradigm change and they have failed to relate the cognitive dimensions of greening to the economic process (see Andersen, 1999, 2010b).

The green paradigm discussion is important for two reasons. First, it puts emphasis on the pervasiveness, radicality and path dependency of the greening process. The global economy is currently highly locked-in to 'wasteful' carbon based technologies and the shift to a low carbon resource-efficient society is therefore likely to be costly and entail considerable creative destruction of infrastructures, physical planning, technologies and practices. Secondly, and much less recognized, it points to the neglected cognitive roots underlying the greening of the economy. According to

[2] Dosi defines a technological paradigm as "a model and a pattern of solution of selected technological problems, based on selected principles derived from natural sciences and based on selected materials technologies", (Dosi, 1982 p.152). A technological trajectory is defined as the pattern of conventional problem solving activity within a given technological paradigm (Dosi, 1982). Technological trajectories emerge because the technological paradigm embodies strong prescriptions on the directions of technological change to pursue (positive heuristics) and those to neglect (negative heuristics)(Dosi, 1982).

Dosi's line of thinking not only scientific work but also learning and "search processes" associated with technological innovation are routinized and path dependent and build on specific heuristics. I propose that the greening process entails distinct heuristics and that it is possible to define a "green trajectory" (see Andersen, 1999, 2010b). Fundamental in the green trajectory is the notion of "resource efficiency", i.e. to achieve maximum service or utility with minimum resource use and overall environmental impact [3](Daly, 1984, WBCSD 2000). Another core element is an understanding of the causal relationship between an agent's given activity and its environmental impact (Andersen, 1999). In modern societies these causal relationships are blurred due to time delays and spatial and organisational displacements (Weichhart 1989; Andersen, 1999). Achieving green awareness and knowledge is therefore difficult and may be more demanding in developed economies than in developing economies, where the linkages between an activity and its environmental impact are more quick and direct.

A general finding of empirical analyses of firm greening show that firms which for a variety of reasons pursue eco-innovation strategizing (green branding) typically also undergo green learning and over time develop lasting green search rules (Halme, 1997; Andersen, 1999, 2010b, Horbach 2005; Wagner, 2008; Andersen et. al. 2010). A techno-economic paradigm entails a notion of "technological progress" which guides the direction of companies and knowledge institutions search processes (Dosi 1982). The evolving green techno-economic paradigm change seems to be leading to the rise of a widespread notion of *green progress* which becomes the positive heuristics to be routinely pursued influencing on the green search processes of firms and knowledge institutions (Andersen, 1999). The notion of green progress will always be subject to some change as the environmental agenda changes but the cumulative nature of the green economic evolution makes it likely that the green positive heuristics will continue to grow.

We may perceive of the aggregate green techno-economic paradigm change as a shift from, and a competition between, a "wasteful" trajectory, where there is little attention to the environmental impact of resource use in (firm's and scientists)

[3] The concept of resource efficiency I use as similar to the concept of eco-efficiency. The term resource efficiency has the advantage that it is immediately meaningful which is not the case for the eco-efficiency term. See WBCSD 2000 for a full definition of the concept eco-efficiency.

normal problem solving activities, towards a "resource efficient trajectory" where firms and scientists routinely have strong attention to and insights into an efficient use of resources (considering the sink (waste) and the source (resource extraction) functions and the closure of the materials cycles) in normal problem solving activities (see Andersen, 1999, 2010a, 2010b).

A key issue is the scope and durability of the greening process. We have seen a very dramatic rapid rise in green economic evolution the latter 3-4 years which we may characterize as a green market take off, following a very slow gestation period starting in the mid 1980s when the first pioneering green proactive environmental strategizing started. What seems to have happened is the emergence of a generally recognized global expectation that the green technological revolution is here to stay, and there is a global race to appropriate the rents from this new profit opportunity. The friction to eco-innovation is, however, still considerable, none the least in transition and developing economies but also in developed economies.
Environmental economists have long argued that in a world of finite resources, such a green technological revolution must take place or environmental disaster will follow. (Daly, 1984,1985, 1991, 1996). The so-called TAP formula informs us why. Environmental degradation is seen as a function of technology development, consumption per capita and population growth (Foster, 1994).

The TAP formula
Environmental degradation = innovation + consumption/capita + population growth (Foster, 1994)

So far the global achieved improvements in resource-efficiency have been off-set by increased total economic growth. That is, the rise in resource-efficiency for a given product achieved through eco-innovation has been off-set by the total rise in the number of products produced. Since we are living in a dense and resource demanding "full-world economy" with still rising population growth and per capita consumption, and is likely to continue to do so for at least the coming 20-30 years, the quest for still more improvements in global resource-efficiency will remain an ongoing challenge to humankind (Daly, 1996). This quest will never go away meaning that any sustainable

economy will have to be a green economy, where eco-innovation has become the 'natural' innovation. The huge and enduring scope of the global eco-innovation challenge becomes apparent. The recognition of this lies behind the recent strong climate agenda but has been nearly 60 years underway.

This discussion has proposed that from an evolutionary economic perspective the greening process is more than a technical substitution process, from none-green to green technologies, but should be seen as a more fundamental learning process, and a very demanding one. It requires a substantial amount of creative destruction of existing none-green capabilities and search practices and the creative accumulation of new greener ones for green markets to become well-functioning and .
Overall, we may perceive of green economic evolution as a transformation of the economic process from a resource-intensive to a knowledge-intensive economy.
In order to become resource-efficient we have to be knowledge- intensive.

Before turning to the greening of innovation systems we have to shortly define innovation systems.

3. Understanding innovation systems

The well-established innovation systems theory seek to take on a systemic perspective on innovation and long-run economic development, emphasizing the institutions that are critical for the economic process as well as the patterns of collaboration and communication that shape the innovation system at any given time.
(see Freeman, 1987, 1995; Lundvall, 1988, 1992 (ed.), 1999, 2005; Johnson, 1992; Nelson, 1993; Metcalf, 1995; Edquist, (ed.) 1997, OECD, 2000, Perez, 2000, Freeman and Loucã, 2001, Malerba, 2006; Fagerberg et all. 2008). It has been further operationalized as an innovation policy frame by the OECD and European Commission (OECD 2000, 2001a, 2001b, 2005; European Commission 2003, 2006). The innovation systems theory emphasizes that knowledge is the core resource in modern economies. National economic performance depends more on knowledge generation, absorption and use than simple labour productivity. 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). Hence the concept is closely related to "knowledge based competitiveness" and the "knowledge economy", or as it is sometimes also referred to, the "learning economy" (Lundvall, 2007, Gregersen and Johnsen, 2008).

The core, or the innovation dynamo (OECD, 1997), of the innovation system is made up of the key knowledge producers and users, notably firms and knowledge organisations. Even though there is much emphasis on the wider institutional setting in innovation system analysis it is the firm, and the interaction of the firm with other firms and knowledge institutions as part of the innovation process which makes up the core focus of analysis (Lundvall, 2007).

The essence of innovation systems theory is to view the economy as resulting from co-evolutionary processes of change in knowledge, technology, organisations and institutions (Malerba, 2006; Lundvall, 2007). Innovation systems develop and transform as firms and other knowledge producers and customers interact with, form and are affected by a (predominantly national) public knowledge infrastructure, policies and wider institutions.

While innovation systems should be considered open systems in which different systems (regional, sectoral, technological) overlap, the frame is primarily applied at the national level. The argument is that despite a globalizing economy, the national institutional setting, noticeably policy, to a high degree seeds the innovation process and learning remains still quite localized (Maskell 1999).

The evolutionary perspective emphasizes routines and path dependency and points to the strong inertia in any innovation system. Changes in one part of the system require complementary changes in other parts. It is therefore important to be attentive to the path dependencies, mis-matches and lock-ins that prevail in different parts of the innovation system. The innovation system functions as a selection environment that tends to preserve existing well-established practices (Nelson, 1993; Metcalfe, 1995, 2003; Smith, 2000; Edquist, 2001, Lundvall 2007). Only the new practices that at a given time and place are well adapted to the continuously transforming selection

environment are likely to take root and come to form the basis for further selection and development.

Empirical comparative analyses of different national innovation systems show that they vary widely in their structural characteristics and innovation patterns (Nelson 1993; Metcalfe 1995, Edquist and Hommen, eds. 2006). None the least the sectoral composition of a given national economy influences greatly on the operation of its national innovation system as innovation patterns of different industries vary considerably (Pavitt 1984, Malerba 2004, Fagerberg et. al 2008).

The perspective of innovation systems forwarded here is the so-called 'organizational' or regional approach which focuses on the organizations and the wider institutional setting which together makes up the innovation system (Lundvall, 1992, 2007). This approach has only been little applied to the environmental area. The alternative 'functionalist' innovation system approach is being rapidly implemented in much environmental and energy research in recent years (see e.g. Bergec and Jacobsson, 2005; Hekkart, 2009, 2010). However, this approach fails in my view to recognize the importance of the time and space dependencies of the economic process. Innovation is a historical process, taking place in real time and space with real actors (organizations) in a given innovation system. It matters where the organizations and the knowledge is embedded, and the organizational approach provides a much more consistent theoretical discussion of these issues than the functional, which appears more as a loose broad bundle of important innovation aspects.

4. The greening of national innovation systems

We do not know much about the greening trends or dynamics of different national innovation systems as this theme has been little analyzed empirically. This section only seeks to suggest some key features of what a green innovation system might entail and suggest some general policy principles. For a more specific policy discussion see (Andersen and Foxon, 2009).

The innovation systems framework I see as linking up to the green techno-economic paradigm discussion above in emphasizing a strong focus on the time-and space dependencies of the green economic evolution. We may perceive of the greening of the economy as a global ongoing but highly uneven transformation process which is subject to specific often very different conditions within widely different national innovations systems.

Green economic evolution, with its high element of policy, and institution formation, offers an interesting opportunity to study long-run co-evolutionary changes in national as well as wider regional contexts. The recognition of the importance of well-functioning institutional structures for a high innovative performance and economic development within the innovation systems framework makes it the more remarkably that the environmental issue has received little attention until now within this line of thinking (see though Hübner et al 2000; Andersen 2004, 2006, 2008a, 2009, 2010b; Kemp and Andersen, 2004; Foxon et al., 2005b, Foxon and Kemp, 2007; Andersen and Foxon 2009 for some mainly policy oriented discussions from this perspective) . Among the core proponents of this framework only Lundvall has discussed the issue quite shortly (Lundvall, 2007). A neglected theme in innovation systems analysis is more generally how innovation systems evolve to handle negative externalities in novel ways and how this effects the overall performance of the innovation system. So far, the historic gap between environmental policy and innovation policy means that efforts to develop eco-innovation policies are only emerging, particularly within the domain of innovation policy (Andersen, 2004, Kemp and Andersen, 2004, OECD, 2009).

The former discussion of the trend towards a green learning economy has already hinted at the co-evolutionary nature of the green economic evolution. With green economic evolution processes of creative destruction and creative accumulation set in and take pace. Gradually green corporate strategies, search rules and capabilities accumulate. Green competitiveness becomes increasingly important and influences still more on the selection of suppliers and customers, learning partners, employees and financial institutions. National and international green formal and informal market supporting institutions are being established sinking the costs of eco-innovation and green marketing. None-green actors are weeded out. As the green

market consolidates less-green sectors and technologies may be threatened by competing greener technological trajectories.
In the final phase, the innovation system has become green which entails that it upholds a high eco-innovative capacity as compared to other economies, i.e. it is a relative measure. The emphasis is on the innovative capacity at the aggregate national level rather than the environmental performance of the economy per sé. This is the important novelty of the innovation system approach as opposed to more traditional economic or environmental approaches. A more absolute measure, but still with an innovation focus, is that eco-innovation has become the 'natural' innovation in the economy (Nelson and Winters seminal term (1982)) where innovation and technology routinely moves in a green direction.
When these goals are met not only at national levels but at the global level, we may refer to the 'green learning economy' as already discussed.

Four core policy targets for achieving a greening of national innovation systems are suggested:

1. a selection environment that favours eco-innovation
2. an efficient organisation of green production and learning across firms and knowledge institutions in the innovation system
3. a strong green knowledge base
4. the creative destruction of institutions and technical infrastructures which hamper eco-innovation and the creative accumulation of new greener ones.

These targets are relevant for both developed and developing economies. The paper argues that greening the national innovation system is an important element in meeting the changing competitive requirements of the globalizing learning economy.

In the green learning economy we find widespread national green innovation systems though in varies stages of development and with variations in their green specialization. In such an economy it is attractive and easy for companies and knowledge institutions to engage in eco-innovation because supporting market institutions are in place and eco-innovation has become the natural innovation that routinely is being pursued.

The innovation system framework more fundamentally points to the need for policymaking to develop *general* attractive conditions for eco-innovations in the given innovation system. It also points to the need to target policies to rectify the system failures to eco-innovation which reign in given innovation systems. If the green market is not well-functioning and supported by sufficient supporting market institutions, if the knowledge base is not sufficiently green, if there are too many bottlenecks among companies or knowledge institutions which hamper efficient eco-innovation across actors, if technical infrastructures hinders radical eco-innovations, it is likely that targeted efforts to support e.g. certain renewable technologies or green cars are likely to fail. The general efforts to green varies national and regional innovation systems may reduce the system failures to eco-innovation and lead to sinking costs to eco-innovation, and thereby a more rapid global green learning and innovation process.

The importance of the national innovation system perspective is none the least the attention it brings to the national green knowledge base as a key underlying factor for supporting eco-innovations, and a recognition of the many different sources of green knowledge which feeds into and become carriers and distributors of this knowledge base. This means that both informal and formal learning in and between companies becomes important, adoption and diffusion of green knowledge

The innovation system perspective may be important to in bringing attention to the need to weed out less–green technical infrastructures which typically reside in the public of half public domain (such as the water and waste system, energy supply system, transport system and urban infrastructure) which are potentially important enablers of more radical eco-innovations, but which today often functions are barriers. Policy resistance to such changes, are however, often considerably as power resides in different segments of the public administration.

Situating this discussion in an innovation system frame it becomes evident, that different countries around the globe are at very different stages in their greening process and thereby face very different eco-innovation conditions.
This is partly due to historic reasons. Most modern economies have a long history of developing the policy frame, sets of institutions and infrastructures to handle and

prevent environmental degradation. This is much less so the case in transition and developing economies, who are also hampered by the general lack of well-functioning institutional systems and much technical infrastructure. On the other hand they may leapfrog some of the unfortunate policies and technical infrastructure which is hampering the development of more radical and efficient eco-innovations in modern economies today.

Even within developed economies we are likely to find very different eco-innovation patterns due to the high importance of national legislation, particularly in the earlier years (the 1950-70s) in this area. Today environmental policy making is increasingly international which increases the green markets and hence profit opportunities.

While national eco-innovation policies take an interest in building and positioning strong green national capabilities as a basis for local green growth, global interests point to the need for technology transfer to and access to finance in those (transition and developing) economies which are less green, as emphasized in the climate policy debate. The innovation system perspective may address both those goals. On the one hand the need to enhance the national green competitiveness by strengthening the national conditions for (eco-)innovation; on the other hand, the need to consider local conditions and absorptive capacities when aiming to facilitate technology transfer between given developed and developing economies, rather than merely focusing on the access to finance.

The eco-innovation angle emphasizes the importance of the degree of company pro-activity towards environmental strategizing as a critical parameter. It is companies who take innovations to the market, but they do not innovative alone. It is fundamental that all (interdependent) companies internalise climate goals in their innovative activities for eco-innovation to take place efficiently on a larger scale. The long regulatory phase have cemented reactive environmental strategies among many companies. This means that there is still considerable lock-in into none-green practices and business strategies in most innovation systems, making up the most important friction to eco-innovation. We need to know more about where the fricti nto eco-innovation resides in given innovation systems. , (Andersen, 2008b). The dramatic change in corporate strategizing the latter years have changed this situation

considerable, but still a core policy focus should be to make it attractive to all firms to engage in eco-innovation, and to secure that all firms are on a similar 'green wavelength' to secure efficient eco-innovation acress firms.

It is likely that, as experienced hitherto, there will be waves in the intensity of the green economic evolution in the future. However, the process is, as any other change process, cumulative and there is no longer any doubt about the climate agenda being generally recognized as an important driver for economic development.

5. Conclusion

This paper has sought to forward an interpretation of the greening process as well as a new innovation-friendly policy rationale based on evolutionary economic theory, a perspective that hitherto has only been little applied to the environmental area. For this reason limited attention has been paid so far towards the special conditions for eco-innovation.

The paper has argued that the global economy is in a process of green economic evolution that should be seen as related to and dependent on the rise of the learning economy and the changing competitive conditions this entails. Other issues than costs are becoming increasingly important for competitiveness, allowing more room for such issues such as environmental parameters to become a selection parameter on the market. Also much more complex demands are possible in the learning economy because of better communication and higher information and knowledge levels, which are necessary for enabling the development of the demanding green market. Shiftning away from a resource intensive economy requires the development of a knowledge intensive economy.

It is further suggested that the global economy is moving in the direction of a 'green learning economy', a process that will entail substantial creative destruction and creative accumulation around the globe and affect all economies. The paper argues that green economic evolution may be characterized as an unusual uneven economic process, and that there is a need for specific national solutions. The paper has further

argued that the organisational innovation system approach represents a needed analytical framework for interpreting green economic evolution at both the global and national level as well as supporting eco-innovation policy developments. The innovation system framework is particularly important in translating macro international environmental goals into national innovation goals targeted to the specific conditions of given national innovation systems. The paper proposes that both developed as well as developing countries may advantageously address this new agenda by aiming for a greening of their national innovation systems.

I propose that the greening of the innovation system entails that it upholds a high eco-innovative capacity as compared to other economies. The emphasis is on the innovative capacity at the aggregate national level rather than the environmental performance of the economy per sé. This is the important novelty of the innovation system approach as opposed to more traditional economic or environmental approaches. A more absolute measure, but still with an innovation focus, is that eco-innovation has become the 'natural' innovation in the economy where innovation and technology routinely moves in a green direction.

Four core policy targets for achieving a greening of national innovation systems have been suggested:

1. a selection environment that favours eco-innovation
2. an efficient organisation of green production and learning across firms and knowledge institutions in the innovation system
3. a strong green knowledge base
4. the creative destruction of institutions and technical infrastructures which hamper eco-innovation and the creative accumulation of new greener ones.

These targets are relevant for both developed and developing economies.

When the above goals are met not only at national levels but at the global level, we may refer to the 'green learning economy'. In the green learning economy we find widespread national green innovation systems though in varies stages of development and with variations in their green specialization. We need global policies aiming for a

transformation to a green learning economy and we need national and regional policies aiming for a greening innovation systems.

The innovation system eco-innovation policy approach strives to create a selection environment which consistently makes it easy and attractive to engage in eco-innovation for all kinds of (interdependent) firms as well as knowledge institutions. Such a policy ambition calls for horizontal policy measures and hence the need for an integrative policy frame as represented by the innovation system perspective. There is a need to identify, through empirical analysis, the specific characteristic, conditions and system failures for eco-innovation in given innovation systems.
There is a need for empirical analyzes into the nature of and trends in the greening of different national innovation systems as a basis of targeted policy measures aimed at rectifying the system failures to eco-innovation in given innovation systems.

The analysis has pointed to the highly uneven nature of the green economic evolution. Overall, there is a need to consider the uneven distribution of green strategies, capabilities and search rules within as well as across national innovation systems at any given time when trying to create widespread incentives for eco-innovation.

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