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*Publication date:*  
2012

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*Citation (APA):*

Andersen, M. M. (2012). Into the Green Economy – Evolutionary Perspectives on Green Economic Change. Paper presented at 14th International Schumpeter Society Conference, Brisbane, Australia.

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# **Into the Green Economy – Evolutionary Perspectives on Green Economic Change**

Paper for the Schumpeter Conference  
Brisbane 2-5 July 2012

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## **Abstract**

The recent ‘greening’ of the economy represents possible one of the most profound examples of economic change. While the environment used to be considered a burden to business this perspective has changed making ‘eco-innovation’ increasingly recognized as a driver of economic development. Evolutionary economic research into the greening of industry and the economy is, however, limited, so explanations of this dramatic change are lacking. This paper seeks to remedy this gap and forward evolutionary explanations and historical cases on the dynamics and scope of green economic change.

The theme of the greening of industry and the economy is of interest because of the focus on the fundamental social and economic difficulties of changing direction in technology. Defining the greening of the economy as a techno-economic paradigm change the paper suggests expanding on Perez’s framework (Perez, 1983, 2000, 2010) of such paradigmatic changes. While paradigmatic changes are often seen as induced by a technological major ‘key factor’, the greening of the economy presents a special case. It is rather, the paper suggest, on the one hand, the evolution of a new green generic trajectory of resource efficient problem solving, and simultaneously, the emergence of new green selection criteria on the market. These lead to a series of interrelated eco-innovations, which gain still more force as the green market matures.

In the search for the origins of paradigmatic changes, the paper suggests to focus on the neglected ongoing firm learning. In seeking to link up changes at the micro-level of firms with macro institutional and social changes, the paper suggests to synthesize insights from the long wave discussion, innovation systems theory and the evolutionary capabilities approach. The change in the underlying technological trajectory and the changes in selection mechanisms, the paper argues, evolve to a large degree as part of interactive, creative economic processes between firms. The evolutionary capabilities perspective is important in contributing to a better micro theoretical framework of innovation systems theory, in contributing to explain when and where interfirm coordination and learning take place and hence the direction of (green) economic evolution. More specifically they are the sum of three interrelated processes. Ongoing (ex ante) coordination, conflictual (ex post) coordination, and knowledge cooperation.

Firms, it is argued, do make each other go green as part of the economic process, entailing major institutional and organizational changes which form important parts of the green economic evolution.

The greening of the economy reflects important features of modern complex economic systems, making room for new broader, value-based notions of innovation.

## 1. Introduction

At the very core of the environmental sustainability agenda lays the relationship between the economy and the natural environment. Since the rise of the modern sustainability agenda around the 1950s when pollution was first recognized as a societal problem of some scale, the environment has been considered a burden to business. Economic and environmental goals have been seen as strong opposites, whether at the firm or societal level. Indeed so far economic growth has been associated with continuous environmental degradation at the global level (Daly, 2005; Andersen, 2009; OECD, 2011). Until recently it was inconceivable that this would ever change.

The point of departure of this paper is to investigate the marked change in this well-established pattern in recent years. To some degree the change is physically measurable. There is evidence of a partial decoupling of global economic growth and environmental impact in the later years (Bleischwitz, 2011). reflecting a rise in the level of eco-innovations (Behind these measures lie changes at the strategic level where a new alignment of economic and environmental goals has emerged the last 5-12 years. The environment is increasingly seen as a business opportunity and a driver of economic development, both among firms and at the policy level where green innovation policies ('eco-innovation' policy, policy for 'green growth') is emerging. This trend is captured most recently by the notion of the 'Green Economy'. The Green Economy has only the last 2-4 years become an established and central policy goal in leading international political organizations such as the United Nations, the European Union and the OECD (UNEP/ILO/ITUC, 2008; UNEP, 2011; United Nations, 2011; OECD, 2011). The concept of the green economy is indicating a competitive restructuring of the economic system, following other recent recognitions of the 'ICT economy' and the 'knowledge economy' (Freeman, 2001; Lundvall, 2007). However, while the concept is becoming more and more widely used, the nature, the origins and the scope of the phenomenon is somewhat unclear, not to say disputed.

This paper seeks to inquire into the dynamics and scope of the emergence of the green economy from an evolutionary economic perspective; that is, it seeks to inquire into the energy within the economic system which has caused green economic change. A fundamental claim of this paper is that the 'greening' of the economy represents the perhaps most profound qualitative economic change so far in modern times. The greening of the economy illustrates more than anything else that competitive conditions are changing over time. The business of business is business, but the rules of business have changed in important ways over the last 50 years. The contours of the green economy we are witnessing in these years where it is becoming possible, and in some sectors and regions even approaching mainstream behavior, to do business coupled with environmental protection are perhaps some of the best evidence of this.

Environmental sustainability is a very large research topic which has been addressed by a range of scientific disciplines, but only very limited by evolutionary economics until recently (Andersen, 2009; Schiederig, Tietze, & Herstatt, 2011)<sup>1</sup>. The theme has been touched upon only shortly by leading evolutionary economic researchers, mainly by (Freeman, 1992, 1994, 1996). The first few

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<sup>1</sup> Schiederig et al. (2011) has undertaken a recent review into 'green innovation management' research, concluding that research is limited and quite recent; they fail, however, to look into the theoretical basis of this research. There is no systematic review into evolutionary economic research on environmental sustainability.

PhDs within this perspective appeared from the mid 1990s. But more widespread in-depth research and thematic conferences, sessions and key notes at the core evolutionary economic conferences such as DRUID and Schumpeter have mainly emerged within the last five years; that is after the establishment of the green growth agenda at the market and policy level. This raises interesting questions into the orientation and impact of evolutionary economics. If the greening of the economy is such a good case of economic evolution why hasn't evolutionary economics addressed this agenda earlier?

The green economic change is of such an economy-wide scope that it involves co-evolutionary changes of science, technology, organizations and institutions. This paper, however, argues that the internal dynamics of economic change must be found primarily at the firm and none the least inter-firm level which is in focus in this paper. Hence the paper seeks to forward a rich perspective on firm learning, emphasizing how the firm continuously learns within, shapes and changes its selection environment.

The paper is mainly conceptual but will also draw in two historical cases, respectively the greening of firms along the paper chain in the 1990s and the greening of firms along the window chain in the 2000s, see (Andersen, 1999, 2001, 2002, 2009, 2010a, 2010b, 2011a; Andersen, Sandén, & Palmberg, 2010)<sup>2</sup>. Wider findings are referred to to a minor degree, a limiting factor being in part the limited research into this, in part the lacking definitions and statistics in the area, meaning that current measurements of green growth trends and dynamics are misleading (Andersen, 2006 ; Kemp and Pearson, 2007; OECD, 2011)<sup>3</sup>.

A point of departure of this paper is that the more dynamic perspective on the economic process forwarded by evolutionary economic theory in several respects may reinterpret important issues in the environmental sustainability agenda. This agenda has been dominated by neoclassical stationary notions of the economy. A claim of the paper is that the neoclassical dominance in significant ways has inhibited a greening of the economy as this research field has failed in realizing and explaining the long run greening of the economy we have witnessed particularly the last 25 years. Orthodox neoclassical economics has at its core the presumption that economic decision making is a matter of constrained optimization within stationary systems of competitive equilibrium. The static assumptions of economic rationality, full information, and perfect markets and given externalities mean that environmental degradation is seen as an inherent market failure and that this condition cannot change. The costs of preserving the environment have to be enforced on companies, the primary polluters, by public regulation. As a result, competitiveness and greening are necessarily opposites. This understanding has not only penetrated environmental and economic policymaking but has also been widely shared by companies. As such it has severely hampered a shift from reactive towards proactive environmental strategies in companies and hence the development of green business models (Andersen, 1999, 2001, 2002, 2004; 2009; Kemp and Andersen, 2004).

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<sup>2</sup> The paper primarily draws on the authors PhD dissertation (Andersen, 1999) which was never published as the author left research afterwards (to develop the first green innovation policy in Denmark). Smaller parts of it is published in Andersen, 2001, 2002.

<sup>3</sup> Current statistics of green growth measures only the traditional environmental sector and possibly the energy sector, the rest is left out.

Evolutionary economists are, in contrast, concerned with how economic systems are transformed from within. Building on Schumpeter, evolutionary economics forwards a vision of economic development as an open-ended process of qualitative change driven by innovation (Schumpeter, 1937/89; Dosi, Gaffard, & Nesta, 2008). Though recognizing that equilibrating forces in the economy are strong, they are considered constantly disrupted by innovation. For Schumpeter, competitiveness depends on entrepreneurial creativity whereby technologies, organizational structures and human skills are combined in novel ways to generate economic value. The innovation driven competition is transitory in nature as swarms of imitators enter leading towards a cyclical economic development (Schumpeter, 1939). These thoughts have further been developed into theories of long run economic waves (Perez, 1983, 2000, Freeman, 1994, Freeman and Louca 2001).

In order to cope with a world of change, firms are presumed to be boundedly rational and follow decision rules or routines. Via search processes firms engage in routine-changing processes (Nelson and Winter, 1982). Attention to the efficiency of routines but also its conservative force remains central to evolutionary economic thinking leading to an emphasis on the cumulative and path dependent nature of search and technological change and the tendency of lock in (Arthur, 1989). Innovation is a force of creativity and economic growth but also a force of destruction. This happens in part at the firm level. As innovations challenge existing practices and beliefs, they make prior knowledge obsolescent and require new thought frames in which the innovations can be understood and handled. And it happens in part at the structural level as the survival of existing firms and sectors may be threatened by radical innovations.

The greening of the economy, it is here suggested, should be seen as an economy-wide techno-economic paradigm change, as also pointed to be several other evolutionary researchers (Kemp & Soete 1992; Freeman 1994; 1996), Wallace, 1996). The greening process is seen as revolutionary in character, entailing a paradigm shift resulting in major cognitive and technological changes. This paradigm change they expect to have thorough structural effects for the economy. These authors, however, emphasize the need for considerable changes at the institutional level for such a paradigm change to gain momentum, rather than offering an explanation for the origin and diffusion of the paradigm change.

Perez (1983, 2000) has suggested an evolutionary model of techno-economic paradigm change leading, she argues, to long run waves in the economy. The starting point is the emergence of a generic 'key factor' with pervasive impacts on the economy. 'Carrier industries' that produce or use this input intensely grow rapidly, induced effects in a number of related industries occur accompanied by innovations in the organization and management of processes using the new input. Gradually new 'technological styles' emerge representing a new 'common sense' way of managing the new technology. The degree of match and mismatch between the new technological dynamics and existing institutional, organizational and social conditions based on the old technology, determines the degree and rate of economic evolution and thereby the length of the economic wave it accomplishes. Freeman and Louca (2001) expands on the mismatch discussion pointing to the co-evolution of five different systems (science, technology, economy and culture), but maintains a similar long wave discussion as Perez. Freeman does not offer any specific explanation of green economic change in his works (Freeman, 1992 1994, 1996).

The greening of the economy, this paper argues has a different starting point and a different character compared to the other paradigmatic historical cases Freeman and Perez refer to. There is no 'key factor' to start the paradigmatic change. Green economic change, while it does entail considerable technological change, should first of all be understood as the emergence of new green se-

lection criteria on the market and new green business models to take advantage of these. Fundamentally, the theme relates to the classical discussion of what determines the direction of technological change, (compare Dosi, 1982). What is it that makes the economy move in a more green direction? We need to look for less technological and more multifaceted explanations than is usually practiced in evolutionary economics.

This paper suggests building on the Perez frame but shifting the attention more to the firm and, none the least, interfirm, level. The interfirm level is, the paper posits, where we find the core micro-dynamo of economic evolution; other macro phenomena may, of course, be equally relevant. An important point is that my (interfirm) learning perspective differs somewhat from usual practices within evolutionary economics. Evolutionary economics is predominantly concerned with learning as deliberate ‘search’ and with occasional (large) innovations; this certainly dominates the long wave discussion of Perez and others. The paper suggests rather setting focus on the neglected ongoing firm contextual learning. The greening of the economy provides a case of how firms continuously react to and shape their selection environment. At the firm level this means how firms’ aspirational goals, knowledge frames, and managerial and organizational structures evolve, take root and spread - become assimilated- in an industrial population. Diffusion takes place as a creative interactive process between firms during which the innovation may undergo change (Freeman, Clark and Soete, 1982).

The theme of firm contextual learning I see as forming a part of the systems of innovation perspective, forwarding a stronger systemic perspective on innovation. The interactions of core actors in the innovation system (user-producers and knowledge institutions) and the wider institutional setup give rise to patterns in innovative behavior in different specific innovation systems (Borrás S.a Fagerberg, 2011; Jensen, Johnson, Lorenz, & Lundvall, 2007; 2007; Nelson, 1993). This approach, however, has an insufficient micro-theoretical framework, having difficulty in explaining when and how the firm more precisely interacts with the different aspects of the selection environment.

The paper proposes that in order to explain (green) economic change it is necessary to synthesis insights from innovation systems theory of adaptive systems and insights on long wave pervasive changes with the micro-dynamics of the evolutionary ‘capabilities’ perspective. This more post-Marshallian tradition brings attention to firm strategic behavior and to an explicit treatment of firm learning and coordination processes on the market, taking a starting point in the relationship between the organization of labour and knowledge (see e.g. Penrose, 1959; Richardson, 1972; Teece, 1986, 1988, 1989, 2000, 2010; Langlois, 1992, 2003, 2004), Teece and Pisano, 1994, Loasby, 1996, 2000).

The study of firm greening through interfirm learning and coordination sheds important lights on the firm - market uneven learning relationship in a changing world and thereby on the theory of the firm (Langlois, 1992). It brings attention to the permeability of firm boundaries and on how the economic process leads to changes in the institutional and technological arrangements of the market and therefore ultimately on how markets are co-ordinated and how market forces may change. In short, the perspective suggested here differs from usual studies within evolutionary economics by emphasizing path change more than path dependency and the nature of firm boundaries more than the locus of the boundary. In this way the study contributes to linking up the open innovation strategy perspective (Chesbrough, 2003) to the macro innovation system and techno-economic paradigm change scheme.

The paper suggests more specifically to see (inter)firm learning as a mixture of search and coordination processes, seeking to embrace learning as an ongoing cumulative process rather than an

occasional ‘stand-alone’ event. Attention is placed as much on the creation of new ideas and understandings as on the accumulation of capabilities. Emphasis on the firm level is placed on the ongoing formation of firms’ knowledge frames and search rules (encompassing both ideas, beliefs and capabilities); at the aggregate level on the evolution of green markets and necessary supporting institutions.

This paper posits that a distinct underlying generic ‘green trajectory’ is emerging. This new trajectory may be conceived as a special kind of ‘key factor’ which potentially feeds into all aspects of the economy. This discussion points to the neglected cognitive roots underlying the greening of the economy. Particularly Dosi’s work on technological paradigm and technological trajectories emphasizes the cognitive aspects of technological retention and change (Dosi, 1982). According to this line of thinking not only scientific work but also search processes associated with technological innovation are routinized and path dependent and build on specific heuristics. A technological trajectory is defined as ‘the pattern of conventional problem solving activity’ within a given technological paradigm (Dosi 1982)<sup>4</sup>. 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).

Following this line of thinking, it is here suggested that the greening process entails the development of novel green positive heuristics and that it is possible to define a distinct underlying “green trajectory” (see Andersen, 1999). The green trajectory builds upon the principle of ‘eco-efficiency, i.e. to achieve more value with less environmental impact (WBCSD 2000). The greening of the economy hence entails the evolution of a new eco-efficient pattern of problem solving activities where it is becoming routine to consider the eco-efficiency of economic activities, which is replacing the old ‘wasteful’ pattern of problem solving activity (see also Andersen, 1999). Little attempt has been made so far to take the technological trajectory and paradigm discussion to the firm level. Teece points out that there may be important implications for firms at the strategy level from relating to existing trajectories and paradigms (Teece 2008). This paper seeks to take this discussion further and investigate the creation and diffusion of new technological trajectories and -paradigms at the firm and interfirm level.

Influencing on this discussion are the special features of eco-innovations. The most important ones are that they are unusually systemic, and have high information problems, as will be elaborated on in the next section. The paper posits that these features mean that firm eco-innovators have to make other firms go green as part of the economic process, and that this happens at an extraordinarily high pace as compared to other innovations, once the greening process has gained initial momentum.

A starting hypothesis of this paper is that the more widespread the interorganisational learning and the more connected, or “specific”, the market relations, the more a green trajectory will spread amongst firms (see also Andersen, 1999). This hypothesis has been confirmed. By looking further into the interfirm interactions it is possible to say more about the friction to but also the direction of further green economic change. I.e. how value chains, sectors, regions or other collections of firms either act as conservative forces restricting the novel eco-innovation, or are swept forward together in an interactive, green creative process, entailing a consolidation and assimilation of their (greener) knowledge frames, search rules, technologies and business models.

The paper is structured as follows:

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<sup>4</sup> 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.

Section 2 looks into what kind of change we are dealing with seeking to define eco-innovation and its specificities. Section 3 investigates the dynamics of firm greening, looking into the strategic and organizational change in firms. Section 4 addresses the wider diffusion and reinforcement of eco-innovation focusing on the interfirm greening dynamics. Section 5 presents a short schematic model of green economic evolution. Finally, in section 6 conclusions are drawn.

### **3. From environmental sustainability to eco-innovation**

One of the most influential ecological economists is Herman Daly. He contributed importantly to operationalizing the sustainability concept arguing that economic development has led to a dense and resource demanding “full-world economy”. The economic growth accompanied by rising per capita consumption and population growth is exceeding the natural worlds carrying capacity, both the source function (the extraction rate of resources versus the regeneration rate of new resources), and the sink function ( the assimilation capacity of the biosystems towards waste and pollution). The ‘empty world economics’ of earlier times, when there was space and natural capital enough to extract resources and emit wastes at a still higher rate, are gone for good. The quest for increases in the global resource efficiency is therefore an ongoing challenge to humankind, only getting more and more difficult as the world gets still more ‘full’ and the global throughput of mass and energy continues to increase (Daly, 1974, 1984, 1991, 1996; Daly and Cobb, 1991). Daly acknowledged that technological change could change this path but he had no expectations that it would ever do so. Even though he was critical to orthodox economics he did not look to evolutionary theories for solutions and treated technological change as exogenous to economic development, similar to other environmental economists. E.g. the environmental economist Foster suggested that the degree of environmental degradation is a function of technology development, consumption per capita and population growth, but insisted on the conservative nature of the economic system, or as he referred to it, the ‘production treadmill’ (Foster, 1994). Daly’s answer to the rising environmental problems was the introduction of ‘Steady State Economics’ arguing that the present growth mania of capitalist societies can only be kept in stock by introducing global quota on resource use and pollution (Daly, 1974, 1984, 1991, 1996).

Evolutionary economic research has, as mentioned so far only to a limited degree been applied to environmental issues and quite late. The evolutionary economic contributions to eco-innovation have tended to have a strong focus on the innovation effects of various environmental regulations, aiming to come up with policy suggestions more than looking into the economic processes involved (Kemp & Soete 1992)(Nill & René Kemp 2009; Horbach et al. 2005; Kemp 1994; Rotmans & Asselt 2001); Wallace, 1995, (Chris Freeman, 1996); Clark, 1996; Hemmelskamp, 1999; Foster and Green, 2000; Hübner et al. 2000; Foxon, 2003; Foxon et al. 2005; van den Bergh et al. 2006, 2007; Stenzel and Frenzel, 2007; Andersen, 2009); Parrish and Foxon, 2009). The most well-established evolutionary economic research in the area is the Dutch-led ‘transition management’ school (see e.g. (Kemp, 1994; Geels & Kemp, 2007; René; Rotmans & Asselt, 2001; Kemp & van Lente, 2011) Kemp and Foxon 2006) The merits of this perspective is that it has pioneered a stronger innovation perspective to environmental sustainability; the limitation is that it maintains a strong prescriptive emphasis on how policies should steer society and innovation towards environmental sustainability,



particularly emphasizing how ‘niche management’ may facilitate large scale, radical green ‘system innovations’. It neglects to look closer into (green) economic evolution and hence the changing conditions for eco-innovation over time. This school is also represented by a large group of more institutional and sociological researchers who have forwarded a ‘quasi-evolutionary perspective’ on wider societal transitions (e.g. Schot, 1991, 1992; (Alkemade, Frenken, Hekkert, & Schwoon, 2009; Geels, Hekkert, & Jacobsson, 2008); Geels 2005, (Tukker, Charter, Vezzoli, Stø, & Andersen, 2008), Hekkert et al. 2007) . For a comment see (Andersen 2008).

Another large and rapidly growing group of research, overlapping the approach above, represents environmental researchers from varied theoretical foundations, which increasingly pick up on innovation aspects applying the ‘functionalist’ innovation system approach e.g. (Geels et al., 2008; Hekkert & Negro, 2009); with its systemic perspective and defined set of key innovation functions it offers an easy access to innovation economic research. However, much of this research refers little to an overall evolutionary economic agenda.

These researchers may draw on (parts of) evolutionary economic theory but they do not seek to contribute to the development of the research area. It is overall, quite typical that much research directed at environmental sustainability is of a mixed or transdisciplinary theoretical basis reflecting its very problem oriented approach<sup>5</sup>. Indeed many of the evolutionary economics contributions so far have been made by environmental economists representing a partial evolutionary economic perspective to vary degrees (e.g. (Rennings, 2000), 2000, Rennings et al. 2003, Beise and Rennings 2005, Jaffe et al. 2005; Frondel, Horbach and Rennings 2005; van den Bergh et al., 2006, 2007).

While research on firm’s strategic response to environmental sustainability used to be limited apart from management literature of a more prescriptive nature, this field of research is exploding in the later years within various lines of business studies and strategizing, focusing on the rise and implications of green business models. This line of research contributes to important new empirical and theoretical insights on the drivers of the greening of industry at the micro-level. This research is partly linked to the evolutionary economics agenda but extends this.

Overall, there has been quite limited evolutionary economics research which has addressed the evolutionary economics of the greening of technology, industry and the overall economy per sé. There have been few attempts to situate the environmental sustainability agenda within evolutionary economic thinking. There are, accordingly, still limited insights on how we might perceive of green economic change as part of overall economic development. This is changing in the later years following the wider recognition of the economic potential of eco-innovations which has led to a rising interest among ‘general’ evolutionary economics researchers into environmental sustainability, or ‘eco-innovation’ studies as it is often termed from this perspective. Accordingly, more ‘pure’ evolutionary economics research is emerging in the area.

### **Defining eco-innovation**

The notion of green innovation, or as I prefer ‘eco-innovation’ has changed over time with changes in the environmental policy agenda. It has traditionally been referred to as “environmental technologies” or End-of Pipe. With a still more preventive and business integrated policy approach to environmental issues up through the 1980s and 1990s the focus has changed from End-of Pipe to cleaner production processes and cleaner products, lately to shift towards the more competitive oriented sustainable innovation, eco-innovation or, quite popular lately, cleantech business. Also low-

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<sup>5</sup> Even René Kemp who pioneered evolutionary economic research on sustainability with the first PhD from 1995 and other early works defines himself as a ‘multi-disciplinary researcher’. <http://kemp.unu-merit.nl/> accessed March 2012.

carbon or climate technologies are important subfields. In accordance with the Environmental Technology Action Plan (ETAP) of the EU Commission, a key policy initiative for the promotion of eco-innovation, two main eco-innovation categories can be identified:

- Pollution- and resource handling technologies and services.
- All technologies, products and services, which are more environmentally benign than their relevant alternatives (EU Com, 2004).

The first group represents the traditional ‘environmental sector’ dealing with waste and emissions which is where the green profit opportunities traditionally have been. The latter group represents the new greening trend of in principle all products. The concept of ‘eco-efficiency’ may help to operationalize the latter, quite vague category. Developed in 1992 by the Business Council for Sustainable Development, (since 1995 the World Business Council for Sustainable Development (WBCSD) it forwards the business vision of ‘creating more value with less impact’<sup>6</sup> (WBCSD, 2000\*). It has also been a pioneering concept in linking up environmental performance to economic performance. Behind the vision lies an operational formula:

**Table 1 Defining eco-efficiency**

$\text{Eco-efficiency} = \frac{\text{product or service value}}{\text{environmental impact}}$
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Source: WBCSD 2000

Eco-efficiency analyses are widely used to measure trends in environmental performance of firms or sectors over time, mainly reflecting improvements in process innovations of single plants. At the aggregate level it is being used to measure the degree of decoupling of environmental impact from economic growth at the global level (Bleischwitz, 2011). Most recently the term eco-efficiency is increasingly replaced by the term resource-efficiency which is becoming a core policy goal. The meaning is, however, today the same, though reflecting a renewed interest in to scarce resources<sup>7</sup>. The term resource efficiency has the advantage that it is commonly meaningful while the eco-efficiency term is more esoteric.

I have earlier suggested that the concept of eco-innovation should represent an evolutionary economic perspective to environmental sustainability (Andersen, 2004, 2008, 2009, 2010a, 2010b). In contrast to other definitions which are based on technical assessments (see e.g. Kemp and Pearson, 2007, Reid and Miedzinsky, 2008) I suggest to define eco-innovation in economic terms. Eco-innovation I define as *innovations which are able to attract green value on the market* (see also, Andersen, 2006, 2009). They (appear to) reduce net environmental impacts while creating value on the market. Hence the concept intersects environmental degradation with innovation and economic performance. The eco-innovation concept here becomes a measure of the degree to which environ-

<sup>6</sup> “Eco-efficiency can be achieved by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and energy and resource intensity throughout the life cycle, to a level at least in line with the earth's estimated carrying capacity” (WBCSD 2000).

<sup>7</sup> In principle resource efficiency only covers the ‘source’ side, but the tem is more and more used synonymously with eco-efficiency (source and sink side included).

mental issues are becoming integrated into the economic process (see (Andersen 2009). The distinct feature of the concept is that it makes no claim on the absolute “greenness” or sustainability of an innovation. Whether an innovation is an eco-innovation or not is defined by the market. In this respect the term distinguishes it self from the related ‘sustainable innovation’ concept used by many innovation researchers<sup>8</sup>. They miss the point that environmental sustainability can only be understood at the global level (Daly, 1974). It is more or less impossible to state whether a single innovation is actually sustainable or will lead to sustainability. None the less, there are continuous heated discussions among researchers of whether varies innovations are green enough to be considered as sustainable innovations, and whether for example carbon sequestration and nuclear power should be included (Kemp and Pearson, 2007). I suggest a different evolutionary framing. The central question is not how green an innovation is at a given time but the *direction* of the innovation process. That is, whether technology and innovative economic activities more broadly are moving in a green direction, where one incremental eco-innovation may induce other related innovations, leading to a still greener technological trajectory. This is what eco-innovation, as here defined, is a measure of.

From the broad definitions of eco-innovation it is apparent that it is difficult to categorize, partly because of the great complexity but also the relativity and hence transitory nature of most eco-innovations (those outside the environmental sector). These are moving targets; innovations which are considered green today may be outrun by greener alternatives over time, either through technological change or through new green preferences or understandings in science and society (Kemp and Andersen, 2004; Kemp and Pearson, 2007; (Andersen, 2006; 2009).

The same argumentation goes for the green economy concept. The green economy should not be considered green in any absolute sense. I do not argue that the green economy is environmentally sustainable. The concept has been much scolded because environmental researchers argue that the level of eco-innovation (or as they say ‘sustainable innovation’) is too low and we are exceeding the worlds carrying capacity. Hence we should not talk about a green economy. Again I suggest framing this differently. The economy, I suggest is green when the selection environment favors eco-innovation to such a degree, that eco-innovation has become the “easy and natural” innovation. In such an economy innovation and technology moves in a green direction. (Andersen, 2004, 2008; 2009, 2010b, 2010c, 2010d).

The green economy is important as a vision and policy goal; we are moving into the green economy. We are far from in it now but important shifts have happened recently where eco-innovation is approaching mainstream behavior in certain parts of the economy representing quite a radical economic change, as we shall return to in section 3.

This is not to imply that we will reach environmental sustainability if we reach a green economy. Many other measures may be needed than focusing on the internalization of environmental parameters in the economic process. The greening of the economy is a necessary and essential but not a sufficient element towards environmental sustainability.

### **Characteristics of eco-innovation**

Eco-innovation, I suggest, is distinct in character in seven ways. It is radical, systemic, associated with considerable information problems, has a normative element, is highly subjected

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<sup>8</sup> Most authors understand the eco-innovation term similar to the sustainable innovation term used here, see e.g. Kemp and Pearson, 2007) but the concept is not used in any consistent way so far.

to policy and NGO attention, the technical infrastructure is important and it is affected by the carrying capacity and resilience of local biosystems<sup>9</sup>.

Add.1) Eco-innovation is *radical* because of its strong cognitive and normative implications; compare the reference to greening entailing a paradigm shift (see further below). While some emphasize how greening entails cognitive shifts ((emp & Soete 1992; Kemp 1994), others emphasize how many fundamental values and assumptions of western industrialized societies, such as time calculus, efficiency, wants, growth and progress and the overall man-nature relationship are ascribed new meanings (e.g. Daly, 1974, 1985, 1991, 1996; Summerer, 1989, Glaeser, 1989, Foster, 1995). The argument forwarded here is that eco-innovations are mainly radical in a cognitive sense, entailing some fundamental new understandings and search rules, while not necessarily in a technological sense (compare Malaman, 1996). It is these new fundamental understandings which are coming to form a new distinct ‘green technological trajectory’ which are a major cause of the green economic change we are witnessing (Andersen, 1999, Andersen, 2001).

Add.2) Eco-innovation is highly *systemic* in character.

The systemic features are due to three factors, two technological and one managerial:

- a) Even though a great deal of eco-innovations are incremental, the transition towards an environmentally sustainable economy necessarily involves considerable radical and systemic change, e.g. related to the ongoing shift from non-renewable to renewable and from carbon based to low-carbon clusters of interrelated technologies. New materials and technological or service solutions may be found, which may lead to disruptions in wider parts of the economic system. The eco-innovation may extend into and affect the technical infrastructure and the social sphere, changing our lifestyles as more resource efficient patterns of production and consumption are sought (as considered by SCP research (‘sustainable consumption and production’)<sup>10</sup>.
- b) Recycling is fundamentally systemic and forms an essential element of environmental sustainability in a ‘full’ society, as it remedies both the source (raw materials use) and the critical sink (wastes) problem (as there is still less space to accumulate waste in); raw materials are saved and waste production is reduced (Andersen, 1999, WBCSD, 2000). There will be increased functional interdependence between manufacturing firms as the material cycles are closing and one firm’s waste products become another firm’s raw material. Production chains change into production cycles. Eco-design for recycling requires considerable coordination along the value chain as all parts need to be made recyclable and fit together.

c) The “life cycle perspective” is emerging since the late 1970s and becoming established in the 1990s as the scientific premise for assessing the environmental sustainability of a product. Now a product is environmentally assessed based on the entire lifecycle reaching from resource extraction

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<sup>9</sup> In (Andersen, 1999, 2009) Andersen, I only refer to the first three main characteristics which are most important for economic change.

<sup>10</sup> The SCP research seeks to encompass both production and consumption processes for sustainable development. The research, however, is often more prescriptive than analytical and tends to focus quite strongly on the consumption part, while having difficulty linking this up to the production side (see also (Maj Munch Andersen, 2008) for a critique).

through production, distribution and use to waste handling (and recycling), in contrast to the former focus on the pollution from single production units. Hereby a firm has in principle to answer for the environmental performance on the basis of the whole production chain, typically with most attention to the firms lying upstream in the value chain. At the firm level, the life cycle perspective is becoming institutionalized in the environmental management systems, via 'green supply chain management' and the rising 'cradle to cradle' management principle (e.g. Seuring et al. 2008). This means that firms increasingly set green demands on each other.

Add.3) Eco-innovation is associated with unusually large *information problems* (see also Andersen, 1999, 2009). Green parameters are credence characteristics which are not apparent from the products or the firm. Some kind of labeling scheme is necessary if the market is to reveal green information. Appropriating green value is thus necessarily associated with the development of different kinds of "green information standards", i.e. standards which verify the green performance of a product or a firm. Furthermore the great complexity, transdisciplinarity and uncertainty of green issues, adds not only to the information problems but to knowledge problems. New knowledge frames are needed for the eco-innovations to be understood.

Add.4) Eco-innovation has a strong *normative* element. It is inherently good to be green, which influences on the incentive structures and stakeholder management.

Add.5) Policy and NGO dependency

Policies play a high role as a driver of eco-innovation, setting the requirements that allow the environmental externalities to be internalized. Fragmented and fluctuating policy measures leads to high uncertainty. Dedicated green NGOs, of which there are plenty, are important players in pushing policymaking and pushing firms towards more radical eco-innovation strategies.

Add. 6) Technical infrastructure and physical planning important

The pre-existence of capital intensive and long-lasting technical infrastructure, and institutions to support them, mainly within water, waste, energy supply and transport systems, condition eco-innovations more than many other innovation. They have a strong preserving factor.

Add. 7). The carrying capacity/resilience of the biosystems matters

For some eco-innovations, mainly process innovations, the carrying capacity or resilience of biosystems at a given time and place matters. While some environmental issues are global (climate change) others are more local (soil and water contamination, smog, availability of drinking water..). These conditions change over time and space. Firms situated in less resilient areas may be pushed or oriented towards certain types of eco-innovation. This affects the regional distribution of eco-innovations.

In Japan the ministry of industry forwarded a new vision of eco-innovation in 2007. Here they define eco-innovations as 'a new field of techno-social innovations that focus less on products' functions and more on the environment and people'. They are based on:

1. zero emission based infrastructures,
2. sustainable lifestyles by selling services instead of products,
3. promoting *kansei values* (sensitivity) (METI 2007)

This definition illustrates a key aspect of the green economic change. The notion of innovation is changing to become more encompassing towards social values than it has ever been before. Which is rather a fundamental change.

#### **4. The greening of firms – green economic change at the micro-level**

The gestation period for eco-innovation has been very long indeed, around 60 to 70 years. A main reason, this paper proposes, is the very slow realization of the green growth potentials among both business and policymakers; in part this is related to historical lock-in, in part to considerable organizational and institutional failures on the market. On the other hand, once the greening of the economy began to take root in the 1990s, the rate of green business development has been relatively fast, and with a recent pace that has surprised many. The mainstream consolidation of the green growth agenda in the second half of 2000s came very suddenly, but it illustrates the presence of strong multiplier effects of green economic change. In this and the next section we will explore these issues more in detail.

The greening of the economy in modern times we may so far divide into three major periods. The first period is the long regulatory or reactive phase, where firms started to engage in green R&D forced to by policy making and under influence by green NGOs. This period starts with the emergence of environmental policies in the 1940s and 1950s, being reinforced strongly in the 1970s and especially 1980s due to rising environmental problems and rising green NGO movements. Very little happened on the business side where firms had reactive or even obstructive strategies towards environmental issues. The second period starts around 1990. In the beginning of 1990s we see the first shift among business as pioneering firms start to search for green profit opportunities, starting very small but gaining some broader volume in the 2000s. The third period starts in the latter half of the zeroes, around 2006-2009, where the green growth agenda gains stronger policy momentum and rapidly becomes much more mainstream and recognized. The greening of the economy is becoming apparent, particularly in the affluent economies (Hitchens, et al. 1998, 2002, Rand, 2000a, 2000b, Ecotec 2002, Esto 2000a, (UNEP/ILO/ITUC, 2008; Wagner, 2008, 2010; UNEP, 2011; United Nations, 2011) Frondel, Horbach and Rennings 2005, European Commission 2006, Johnstone, 2007, OECD, 2008, 2009, 2010, 2011)

These shifts are due to co-evolutionary changes at the bottom (in knowledge, technologies, organizations) and the top (the institutional setting none the least policy rationales); in this section we will mainly focus on the central economic processes going on at the firm and market level, while recognizing that wider factors are playing a role too but go beyond this paper to deal with in detail. I will, though, just mention four major international political events or trends which have been milestones in the greening of the economy. The first is the UN Brundtland Report (Our Common Future) from 1987, which seriously set the environmental sustainability agenda on the international policy arena. The second is the influential UN Rio Conference in 1992, which reinforced the sustainability agenda and for the first time pulled in the business perspective and business representatives, leading to the creation of the World Business Council for Sustainable Development (in 1995). The third is the entry of pioneering ministries of industry and innovation and OECD developing new green innovation strategies from the end 1990s and picking up at the

latter half of the 2000s. The fourth is the new alliance between energy policy, climate policy and security policy occurring in part leading up to the UN COP15 meeting in 2009, creating a new very powerful agenda. Sustainability moved from peripheral to central policies by ministries of state and economics( Andersen 2005, 2009).

When considering the drivers to firm greening it is important to recognize that for 70 years firms, outside the environmental sector have generally had obstructive, reactive or indifferent (if not targeted by policy) strategies to eco-innovation, only engaging in environmental R&D when forced to by policy making. Hence as a starting point eco-innovation has been considered something negative, associated with extra costs of emission and waste handling and administrative burdens. Firms developed reactive strategies, accustomed to awaiting regular new demands from the authorities and adjusting their R&D accordingly. There is, therefore, still much friction to eco-innovation on the market (Andersen, 1999; 2009; Kemp, Andersen and Butter 2004).

There is general agreement that the drivers for eco-innovation at the firm level are multifaceted and go beyond direct cost considerations (Horbach 2008; Wagner, 2008; EIO, 2012) Key drivers for firms to build a greener profile are: 1) Employees/human resource management, 2) improvement of image, 3) keeping ahead of government requirements, 4) pressure from customers, 5) reducing production costs and 6) new market opportunities (The Danish Ministry of Trade and Industry, 2000). The latter two are those most directly related to green competitiveness where firms either reduce their production costs by introducing process eco-innovations (resource efficiency measures) or differentiate their products or firm with a greener profile. The product or the firm is becoming a selection criterion on the market, in some cases even attracting a green premium price. Often these two types of green competitiveness are related as process oriented eco-innovations may result in product eco-innovations. A firm may first achieve cost savings by introducing resource efficiency measures in its production of say, trousers, and then achieve a green premium prize when the trousers are marketed as a green product with an eco-label. In the case of more radical product eco-innovations, the ‘greenness’ of the product is often less associated with the production process but lies more in the user phase, say e.g. in the case of windmills or low-temperature, efficient washing detergents.<sup>11</sup> The eco-innovations may, as other innovations, be technical, organizational or marketing innovations as long as they improve the “green competitiveness” of a company (Kemp and Andersen 2004; Reid and Miedzinski 2008).

This paper claims that firm greening is unusually uneven in nature, due to sector specificities. An important and much overlooked aspect is that the incentives for engaging in eco-innovation strategies vary widely for different types of firms and sectors depending on the “environmental sensitivity” of the firm or the sector (see also Malaman, 1996; Andersen, 1999). Firms are affected very differently by green issues depending particularly on three aspects: First, the nature of their technologies; some sectors are inherently more resource intensive or polluting than others. Secondly, regional differences in the resilience of the bio-systems varies and thirdly, their history, noticeable the environmental legislation or NGO pressures they have been exposed too.

Hence the paper posits that green economic change is unusually uneven. Firm response to greening is highly asymmetric; there is an unequal distribution of green incentives, green strategies and green capabilities among firms on the market. With the greening of the economy this is changing somewhat the latter years, as we see a rise of corporate eco-innovation strategizing on a larger scale. This unevenness functions as a barrier to eco-innovation as many firms (the laggards) function as

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<sup>11</sup> For early work on a taxonomy of eco-innovations see Andersen, 2008

bottlenecks for the eco-innovation processes but also as a drive of green economic change as firms have to make each other go green in order to attract green value (Andersen, 1999)

Studies of the economic impact of firms' environmental profile show a somewhat mixed picture (e.g. Carl Bro, 1999; Horbach 2008; (Wagner, 2010);EIO 2012). These studies, however, often fail to situate the analysis in a historical context. The evolutionary perspective, rather, suggests analyzing how the conditions for green competitiveness have changed over time and space. And emphasize more how these conditions may differ between different types of firms and sectors.

An important point and quite a distinct feature of eco-innovation is, however, that firm greening not necessarily is the result of a deliberate strategy but may have a more emerging character. Other researchers have pointed to the fact that many eco-innovations take place unintentionally, as firms carry out e.g. resource saving technologies without considering or marketing these as eco-innovations. These are seen as a matter of traditional cost saving measures (see e.g. (Kemp 1994; Kemp & Oltra 2011). But this phenomenon hasn't really been explained, neither how such green activities may begin to form part of a green business case. For this we turn to the discussion of Langlois (1992) of the uneven firm-market innovation.

The relative developments in firm - market greening is a core factor, as firms and their surroundings go green at uneven paces. At times it is the firm which develops more proactive green strategies ahead of the market seeking to set the standard for what is green. This forces the eco-innovators to turn into green market makers (see more later on this); at other times it is the market which is ahead of the firm and defines what is green. Hence some firms start to go green because they at a given point in time and space find that their selection environment already defines their activities or part of them as green and that low-hanging green profit opportunities are available. Innovations that were initiated with no green business intentions may evolve into a green profit opportunity at some time, and possibly develop into targeted green strategies and fully fledged green business models.

Vice versa some firms find that their activities at a certain time and place are being defined by the market as less-green or even very environmentally harmful. These firms and sectors are threatened to be 'creatively destructed' by the greening of the economy. This may lead to defensive strategies, where firms avoid or lobby to resist green targets; or it may sparkle proactive strategies, as firms and sectors set to prove that their firm or product can turn green.

Firms in the paper industry were among the pioneers to develop proactive eco-innovation strategies in the early 1990s<sup>12</sup>. The reason is two-fold. A heavy pollution profile combined with low-hanging green marketing opportunities. The industry belonged to the more polluting, with a very visible point-source pollution (rivers turning white with waste water from the paper mills, fish dying ect.), and huge amounts of solid paper waste, a core concern then. Accordingly, they were early targeted with environmental regulation and subjected to critique by green NGOs forcing them to engage in environmental R&D and reconsider their environmental profile. At the same time the paper industry was also among the traditional recycling industries. Old cloth and waste paper had long been an important raw material in the paper industry. As policies to enhance paper recycling rose in the 1980s as part of more waste -preventive policy measures (consisting of collection schemes and

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<sup>12</sup> The following account builds mainly on an in-depth analysis made in (Andersen, 1999).



eco-labels), recycled paper became one of the first symbols of green consumer products. Consumers took a first active green stance as they voluntarily participated in paper waste separation (late glass followed and much later plastic). The Danish paper industry was and is very small, consisting of only a few companies. The industry was facing difficult competitive conditions surrounded by some of the world's largest paper industries in Sweden, Finland, Norway and Germany. The mills in these countries were generally newer and bigger, the latter factor essential for the productivity of these process industries. As paper production is highly capital intensive, the strategy of the Danish producers were to upgrade the existing machinery.

An example of an emerging green firm is Grenaa Papir; a Danish company producing nearly 100 pct. recycled corrugated board. They traditionally used waste paper entirely for economic reasons, as it was more economic than wood in a Danish setting, and quite common within most board segments (in opposition to paper segments). However, as recycled paper began to be framed as a 'green product' by society, the firm started to market their products as green products towards their business customers, now stamping the corrugated boxes with the popular recycling symbol. The green marketing became a new, not very central, element among the other quality criteria of the product. The redefinition of their products into a green product, however, was accompanied by learning processes and the appearance of new green search rules within the firm. Having made the first material input-output model, the head of production realized how resource inefficient their production had been hitherto, and extensive measures were made to make the production method more resource efficient. The mill achieved major productive gains and cost-savings through these measures. The mill, known to be very innovative, engaged in the mid 1990s in a radical eco-innovation, becoming one of the first paper mills in the world to obtain a 100 pct. closed water circulation system, technically very difficult together with a 100 pct. waste paper based system (which causes somewhat unpredictable contamination of the water). For this firm, the environmental activities remained primarily embedded in the production and development activities. For some years the firm competed successfully, but had to close down eventually, as its paper machine plant was simply too small compared to the foreign competitors. A high green profile is no guarantee for competitiveness.

An example of a sudden deliberate green strategizing is the small Danish Paper mill Dalum Papirfabrik. Their production of office paper was seriously threatened by the large and more productive paper mills of their competitors. In the mid 1990s they developed a strategy to exploit the new green profit opportunities, and shifted their production to 100 pct. recycled high quality office paper (trying to make it look whiter than the existing competitor Steinbeis' similar recycled product), a rare niche product at that time and quite a radical and demanding innovation. They started to market their product as a green product taking a small premium price. The company was quickly bought up by the large Stora multinational paper corporation who was interested in the green niche as part of their portfolio, but later sold again. Although competing on green issues was difficult in the beginning, the firm still survives with this green niche product as the only remaining paper production in Denmark (excepting board production). While recycled paper is still recognized as a green product the competition from multiple other types of green products today means that the product distinguishes itself less than in the early pioneering 1990s when there were few other green products available in the shops.

Another example of an emerging green firm, who, however, quickly developed more deliberate green strategies, is the Danish paper mill, Brødrene Hartmann. This firm was and is an internationally leading producer of moulded board for packaging, mainly used in egg trays and vegetable trays as well as machines for producing moulded board. They also relied traditionally on 100 pct. waste paper, as their competitors did too. With the greening of the market they identified a new profit opportunity in developing customarized packaging products for industrial customers replacing PVC based packaging. PVC was at the time receiving strong critique and much policy attention for its

contribution to highly toxic dioxin pollution through waste incineration. PVC was, opposite to recycled paper, one of the earliest symbols of a ‘none-green’ product, much scolded by green NGOs, which also consumers learned to avoid in the 1990s. This allowed Brødrene Hartmann to compete very successfully within this segment. The PVC industry is still among those sectors whose survival is seriously threatened by the greening of the economy, as they can never achieve a positive green profile due to the nature (the chlorine content) of their raw materials. Within Brødrene Hartmann, on the other hand, we see the strengthening of green search rules accompanied by a range of eco-innovative activities leading to greater resource efficiency. Taking environmental issues to the strategic level of the firm the firm became a pioneer within organizational and marketing eco-innovations, developing some of the most advanced environmental management systems, life cycle assessments and globally reaching green supply chain management systems. The firm early obtained a reputation as a leading green pioneer among Danish companies.

In 2004 the two top environmental managers and green entrepreneurs in Hartmann were headhunted to another very big Danish company, Novozymes, illustrating the new demands for these capabilities in the 2000s. Novozymes, a world leading producer of biotechnology, were seeking to strengthen their environmental profile and business model further, increasingly marketing themselves as a green firm. With the vision ‘To drive the world towards sustainability’ the firm profitably develops a still wider range of enzyme based green products. Many are directed towards improving the resource efficiency of industrial processes, in. e.g. the textile, leather, brewing and paper industries where the use of enzymes particularly reduces the use of water and harsh chemicals. Other well-known green products of Novozymes are low-temperature washing detergents and biofuels.<sup>13</sup> Competing on green parameters is central to the biotech firm, representing a competitive advantage to the traditional chemical industry, who is increasingly threatened by the greening of the economy. Novozymes is today known as one of the world leading green firms, having received no less than 15 recognitions (listings) as a top world leading sustainability company<sup>14</sup>. Brødrene Hartmann, in the mean time, remains a company where a high environmental profile forms an integrated part of the business model but where the main opportunities for appropriating value from their green profile seem to have lessened somewhat as other eco-innovators have swarmed in.

The construction sector is an example of a business area where green profit opportunities on a larger scale have been pursued somewhat later and where detailed regulation has played a very direct role on the eco-innovation strategizing. The sector is known to be conservative, low R&D and little innovative, knowledge accumulation being hampered by the project like nature of much of the innovation. The construction sector is none the least interesting in an environmental context because buildings account for approximately 40 pct. of overall energy consumption<sup>15</sup>.

For the early eco-innovations in construction in the 1970s, 1980s and 1990s dedicated green entrepreneurs played important roles in developing radical product innovations such as e.g. unburned clay houses, root zone waste water treatment plants and separation toilets which were applied in ‘eco-villages’ experimenting with sustainable lifestyles rather than on more commercial markets.

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<sup>13</sup> <http://www.novozymes.com/en/sustainability/sustainable-solutions/Pages/default.aspx>

<sup>14</sup> <http://www.novozymes.com/en/sustainability/recognitions/Pages/default.aspx>

<sup>15</sup> This section is based mainly on an in-depth case study into eco-innovation strategies in the Danish window chain, see ( Andersen, 2010a, 2011; Andersen et al., 2010), unless otherwise stated.

The interest among incumbent companies was often limited towards these technologies (see Andersen, 1995).

In the window chain an example of early strategizing for eco-innovation is found among the large R&D intensive flat glass producers. Competition in flat glass is intense, technology based and capital intensive leading to a high concentration in the sector, where a few multinational companies have come to dominate. Policies for energy efficiency in windows were introduced already in the 1940s, making double glazing mandatory in new builds in some countries, including Denmark. Soon limitations in the energy emissivity of the glass panes followed and continued to be strengthened regularly ever since. For the glass producers double glazing was attractive as this meant they could sell double as much glass as normally. They accordingly saw energy efficiency as a business opportunity and adopted proactive eco-innovation strategies, seeing an interest in stricter environmental regulations which would lead to a rising demand for glass, e.g. by renovating buildings with more energy efficient windows. Advanced nanotechnology based coatings have been developed over the years meaning that modern glass is multifunctional consisting of up to seven layers of coatings. Apart from low-emissivity glass also solar control glass (reducing the need for ventilation) and self-cleaning glass (reducing water and detergents) are important eco-innovations.

The degree of product innovation into low energy windows has meant that the best of the windows now contribute to zero emission buildings or even plus energy buildings. The most energy efficient windows are now more energy efficient than well insulated walls. By far most of this eco-innovation has been undertaken by the glass companies, to some degree as a spillover from the more innovative car industry, the second biggest customer of flat glass. Today, low energy and solar control glass are standard in modern windows in many countries in new builds. Still, the market is enormous as buildings in many parts of the world, e.g. in the US, have standard single glass installed.

The Danish window producers, one step up the value chain entered into eco-innovation strategizing later. The environmental regulation had targeted the glass while ignoring the frame and the sill. Also, as part of the extensive policy measures to improve the energy efficiency of buildings following the energy crisis in 1974 the Danish authorities introduced limitations in the amount of windows that were allowed in new buildings (first time in 1979 and only left out in 2006). This led to defensive strategies among the window producers where the environment was seen as a strong threat to their business. While the glass had become quite green the window frame had not, and policymakers and users were late in realizing that the window frames functioned as a thermal bridge. Design and maintenance were and still is an important product criterion and elegant wood-alu windows became popular on the Danish market in the 1990s and remain so in the 2000s and 2010s despite the fact that they are little energy efficient. Only in 2006 were more flexible 'energy frame' policies introduced, where the entire energy performance of a building based on energy labeling for windows were introduced. This gave stronger incentives and flexibility for eco-innovation among window producers.

At the same time, the second half of the 2000s, the hot climate agenda made energy efficiency a new top political international target. This and simultaneously novel rising political talks of green growth strategies and opportunities at national and international levels caused a marked change in corporate strategizing. All actors in the Danish window chain are now on an intensive search for new green profit opportunities, also very much the window producers.

The Danish window industry consists of 300 smaller producers but is dominated by one large Group, VKR Holding which has a high level of R&D, especially compared to its smaller competitors. From the end of the 1990s and up through the 2000s and ongoing VKR Holding is strengthening their eco-innovation strategies. This has led to a broadening of the portfolio. While originally specializing in windows the company operates today in 4 business areas: Roof windows & sky-

lights, Vertical windows, Solar thermal energy and Ventilation & indoor climate. In 1998 they formulated a strategy to move into solar energy and from 2002 strengthened the aim to become one of the leading European suppliers of solar thermal energy now consisting of six companies operating internationally. Within ventilation they develop and market environmentally sound ventilation solutions for energy efficient buildings, manufacturing mechanical and natural ventilation systems in companies in five countries and sales companies in nine countries within Western Europe<sup>16</sup>. Today VKR Holding employs around 150 companies, with a total of approx. 15,000 employees in more than 40 countries.

These organizational changes reflect an interesting strategic change among the two main Danish window producers, Dovista and Velux, which are the core companies within the VKR Group. These window producers are increasingly engaged in systemic eco-innovation at the building level, integrating windows with advanced electronic systems and the design of houses for optimal utilization of daylight and natural ventilation. They are, in other words, shifting from focusing on developing windows to acting as developers of green buildings. They seek to exploit the new green business opportunities related to forwarding daylight as an alternative to artificial lighting (lamps, which lately have been targeted strongly by policy making, leading to an outfacing of the energy inefficient incandescent bulb) which could boost the demand for windows, none the least roof windows, which is the core business area of VKR. Similarly, windows could play an important role for natural ventilation. VKR Holding's business model is now based on 'investing in daylight, fresh air and a better environment'. They seek to forward the concept of the 'active house' (as a critique of the reigning low energy 'passive house' concept showing that it is possible to build energy efficient houses without compromising on light, indoor climate (in the still tighter energy efficient houses) and the well-being of people. They now function as the main actors in several green demo house projects in Denmark and Europe. In this way they are threatening the position of existing architects and construction companies, overtaking a new role as designers and system integrators on the green building market.

The more systemic eco-innovations VKR is targeting reflect newer tendencies in the more mature green economy, where stand-alone eco-innovations have been much criticized, and new smart, integrative and systemic solutions are increasingly in demand; solutions such as smart green buildings, smart grid, smart transport systems, which are sought integrated under the umbrella of smart cities. The central role of ICT for much advanced eco-innovation is apparent. The 'smart' angle illustrates attempts at achieving higher resource efficiency at the overall system level, but also, at least to some degree, to align eco-innovation with comfort and modern life styles; still a disputed theme among sustainability researchers ((EIO, 2012). The rise of the high-tech science based smart green city concept illustrates that much has happened to the eco-innovation agenda since the early eco-village concept based on low-tech, mainly experience based development and the insistence of alternative life styles.

Coming back to window innovation the production of wood and alu-wood frames continues to be the main standard in the VKR Group, which needs to be able to supply large quantities in a verified quality. But several more radical eco-innovations directed at the window frame are being developed these years, both within VKR and among other smaller incumbent window companies. An example of the latter is the small Danish company Protec, which recently shifted from alu-wood production into developing window frames made from composite materials, a much more energy efficient ma-

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<sup>16</sup> See also <http://www.vkr-holding.com/4,-d-,0%20Om%20VKR%20Gruppen.aspx>

terial. So far competing successfully on the basis of this green product. Also the firm Dovista, belonging to the VKR Group, has succeeding engaged in the development of composite window frames, also aimed at the market for energy efficient windows. So far they are still under development, only being applied in green demo houses. Another incumbent, Herning Vinduer, is engaged in early development of nanotech (aerogel) based high –efficient but expensive insulation in window frames in cooperation with the large Danish insulation company Rockwool, who hitherto has not been active on the window market.

Also new ventures are on the lookout for the green profit opportunities. E.g. the small Danish up-start company Superwood from 2002 has developed a new patented environmentally friendly method for wood preservation based on nanotechnology (the ‘supercritical technology’). In 2006 the company was bought up by VKR. The ‘superwood’ is already commercially available for consumer use and the market is expanding, presenting a rising threat to conventional preservation products which are highly toxic. The VKR Group is testing the wood in their green demo houses and is engaged in further product innovation to serve the specific needs of window production.

As the cases above have indicated, the conditions for firm greening have changed considerable over time both within and around the firm and none the least in the space between firms. A central parameter here is that, over time with the greening of the economy, we see signs of a leveling of firm greening. Firms are increasingly on a similar or at least less dissimilar, ‘green wavelength’ (compare Andersen, 1999). Wider empirical studies confirm that there are major discrepancies in firms’ strategic response to greening, but that these are lesser in recent years (see e.g. Madsen and Ulhøi, 1995, 1996; Lanjouw and Mody, 1996; Neergaard et al. 1999; Carl Bro, 1999; The Danish Ministry of Trade and Industry, 2000; Brunnermeyer and Cohen, 2003; Mazzanti and Zoboli, 2005; Chen, Lai and Wen, 2006; Horbach 2008, Oltra and Saint-Jean, 2009; Bartlett and Trifilova, 2010; KPMG, 2011; Wagner 2008; EIO 2012; Flash Eurobarometer 342 2012).

However, these results are somewhat fragmented. The limited evolutionary economic research into the greening of industry per sé means that possible patterns in the greening of industry, and the identification of the leaders and laggards in the eco-innovation processes still are in need of further investigation.

In the section below we will look closer into the economic dynamics of green economic evolution, from firm innovation to wider diffusion and consolidation.

## **7. The diffusion and reinforcement of eco-innovation – evolutionary explanations**

Evolutionary economics is good at explaining how economic systems via satisficing behavior and increasing returns become locked in to a certain path. It is easy to understand why the economy has been locked into a wasteful trajectory since the rise of the industrial society, and why the endurance of this path still causes considerable friction to eco-innovation. It remains, however, a challenge to explain how these path dependent processes have changed allowing for the new greener path which have been illustrated in the section above to evolve and grow.

As supported by assumptions in innovation systems theory, social, institutional and organizational factors may not only constrain innovation but may also enable innovation (Borrás S.a Fagerberg, 2011; B. Lundvall, 2007)Lundvall, 1992\*. The greening of the economy is very much an example of this. New policy rationales and institutions, new consumer preferences and lifestyles and new values are important explanatory factors for the greening of the economy (as will be elaborated on in section 8). But the question is how these wider changes in the selection envi-

ronment influence on and are influenced by the firm, the central entrepreneurial agent. A central, but somewhat neglected question in understanding variety creation and more fundamental paradigmatic changes in the economy is *how the firm, perceived as an open system, learns and acts* as part of the wider economic and social system(s) it belongs to). This is the focus of this section. This perspective entails pulling in insights from business studies and learning theory but also more post-Marshallian perspectives are helpful.

The innovation systems theory points to user-producer learning as a central dynamo of knowledge growth and economic change (Lundvall, 1988, 1992\*). Taking a point of departure in this assumption little attention has been paid to specify the direction and dynamics of these processes. Can we be more specific about through which channels and processes new ideas, understandings, search rules and practices are created and assimilated in an industrial population? And how institutions are created to support and consolidate these economic processes? Synthesizing insights from innovation systems theory with post-Marshallian works of particularly Richardson, (1960, 1972), Loasby (1986, 1996,1998, 1999), Langlois (1992, 2002, 2003,2004) and Casson (1997), the evolutionary capabilities perspective developed here suggests that this takes place through vertical and horizontal economic processes of firm interaction.

Expanding mainly on Langlois (1992) and Casson (1997), the “dynamic transaction costs” theory sought developed and shortly applied in this section seeks to encapsulate the incentives and the costs of (green) learning and coordination between firms, both vertically and horizontally (rather than focusing on how they may lead to vertical integration as Langlois does (Langlois, 1992). The analysis seeks to embrace the many-sidedness and ongoing nature of interfirm learning which may take place deliberately but also unintentionally and tacitly. All complex information exchange between firms is seen as a potential source of learning (see elaboration in Andersen, 1999). I am proposing three types of processes, the first being the most neglected and most important:

- 1) Firms engage in ongoing, or ex ante-, coordination, engaging in dialogues, scanning and the creation of market supporting institutions with vertically interrelated firms to ensure that they ‘stay on the same wavelength’, i.e. they coordinate to prevent that their capabilities do not go obsolete. The ex ante coordination processes are central for the formation and shaping of markets between interdependent firms. These are facilitated through investments in ‘mediating institutions’. These I divide further into ‘relational assets’ (compare Lazarick and Marengo, 1997) and market supporting ‘standards’. These two forms of institutions are suggested here as alternative means of overcoming the information problems on the market (compare Richardson, 1960; David, 1985; Loasby, 1996; Casson, 1997).
- 2) Firms engage in ex post coordination when innovation has rendered market capabilities obsolete. Vertically interdependent firms then need to make their innovations compatible through persuasion and teaching or - alternatively - integrate (Teece 1986,2010,; Langlois, 1992).
- 3) Firms engage in knowledge cooperation with other firms, because they can access more capabilities than they can control (Loasby, 1996). This may take place vertically or horizontally.

The novelty of the argumentation lies, not in the elements which are known, but in their interrelation and their claimed learning effect. They each contribute in their way to the coordination of firms’ activities and directly and indirectly to firm knowledge assimilation as part of the econom-

ic process. Paying attention to how these three interrelated micro-processes differ in their incentives, their form and their costs, and thus in their extent and configuration may inform us more on the direction and scope of ongoing economic change.

This paper only allows for a short empirical illustration of these processes in the context of green economic change. Most emphasis is placed on the first process, the *ex ante* coordination, which has the highest transformative power, certainly in the green case, and thus, it is here argued, is central for green economic change. The section builds primarily on findings from Andersen 1999\*, and in part (Maj Munch Andersen et al., 2010)..

### **Green *ex ante* coordination – ongoing user- producer coordination**

Empirically, the *green ex ante coordination* consists mainly of the green dialogues and demand setting processes related to the formation and shaping of markets; i.e. the explicit inquiries, pressures, and requests between suppliers and customers. A core argument here is that the unusually high information (and knowledge) problems related to eco-innovation, means that firms have had to invest heavily in a rising number of still more demanding green standards to verify their green performance. This has been the primary cause of green learning within firms as well as between firms causing shifts in thought frames and strategies and expansionary effects in the value chains.

In the early days of rising eco-innovation activities in the 1980s and the 1990s green market supporting institutions were absent. The direct personal dialogue between users and producers on environmental issues was difficult and demanding as common codes of language and shared understandings of novel, quite complicated environmental issues were lacking. New green relational assets, such as new information codes and new channels of communication, had to be built especially upstream where many firms had been less subjected to environmental regulation and had no experience with working with environmental issues. E.g. in the paper chain Danisco Paper developed a new technical customer service function to handle the more complicated green dialogues emerging with their customers in the paper processing and distribution industries.

However, informal dialogues, while important, do not suffice to coordinate the demanding green market. Going green entails obligations towards the market. The stronger the firm markets itself as green, the more it needs to prove that this is the case. The long history of obstructive and reactive behavior among firms to environmental issues influences on these processes. Pioneering green firms were met with a lot of skepticisms and attacks of ‘green washing’ from green NGOs. In fact many of the early green firms experienced slow return on investments and were surprised to find that the green products did not sell themselves. Danish studies from 1999 shows that approximately half of the companies who had invested in environmental management systems by then believed this had improved their competitiveness directly or indirectly, the other half did not (Carl Bro, 1999).

In order to appropriate green value firms have had to engage in active green market making, via developing or implementing green information standards. The problem for the early eco-innovators in the 1980s and early 1990s was that the green market standards were not there. These standards have evolved over time, most emerging in the 1990s but continuing to develop in numbers, scope and complexity, co-evolving with the greening of firm strategizing illustrated in the former section.

The theme of the evolution of these standards is quite big and goes beyond this paper. Only a few core issues are touched upon here. The standards are registered or verified by third parties, noticeably the European Union which has legislation for e.g. the rules of ecolabelling and environmental

management systems, and the International Organization for Standardization (ISO) within the ISO 14000 family. ISO developed a commitment to support the objective of sustainable development following the central United Nations Conference on Environment and Development, in Rio de Janeiro, in 1992. Key standards are within environmental management systems, labeling systems directed at the consumers or professional users, LCA and standards for environmental accounting, measurement and reporting (the Global Reporting Initiative (GRI) and the International Integrated Reporting Committee (IIRC)). Today, a range of well-recognized lists exist which benchmark the world's top sustainability firms, the most well-known being the Dow Jones Sustainability Group World Index, introduced in 1999, which tracks the financial performance of sustainability leaders<sup>17</sup>.

Underlying the standards lies developments within environmental and sustainability research, noticeably within measuring product environmental performance, the LCA perspective. The original idea of a comprehensive multicriteria life cycle assessment (LCA) of products originated in the USA, in the late 1960s in the Coca Cola company<sup>18</sup>, developed slowly in the US and simultaneously in Europe in Dutch universities during the 1980s, to become established as a research area within the Society of Toxicology and Chemistry (SETAC) in 1990. SETAC started the LCA standardization process which culminated in the LCA guidelines in 1993. Today, research in LCA worldwide is substantial with SETAC remaining a cornerstone of the research community (Hunt and Franklin, 1996; Gabutler, 1997). Research shows that already in 1997, LCA was well integrated into business activities in many large Nordic manufacturing companies. LCA is an integrated part in strategy development, process and product development and, in part, marketing, including use in environmental performance indicators and product declarations (Hanssen, 1999)<sup>19</sup>.

The LCA research continues to be important for the green economic evolution as developments in methods and new findings continues to redefine what is green. E.g. many green companies have found that their green products were not as green as they expected or that the green effect lay elsewhere than expected. Studies within LCA have even questioned the greenness of well-conceived green products such as windmills (nobody even inquired into the greenness of the production of windmills until up in the 1990s), organic meat production and energy efficient windows, though these findings may not reach a wider audience, or only gain ground with time delay<sup>20</sup>. The LCA has lately been challenged by simple Footprint benchmarking measures such as the Carbon Footprint and the cradle-to cradle eco-design –approach which is gaining interest among firms as it is more management oriented and communicative, but less quantifiable<sup>21</sup>.

Another important trend is firms committing themselves to sustainability by signing up to vary treaties. The most significant is the UN Global Compact established in 2000. Signing up implies implementing the Global Compact's 10 principles in the areas of human rights, labour, environment and anti-corruption. Progress is to be demonstrated in yearly reports (Communication on Progress (COP)), but the compact has received critique as it contains no measures to sanction members who

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<sup>17</sup> <http://www.sustainability-index.com/>

<sup>18</sup> The initial analysis developed by Coca Cola and a US research institute led e.g. to the shift from glass to plastic bottles by Coca Cola, as plastic bottles were proven not to be the environmental villains they had been considered so far.

<sup>19</sup> The analysis is based on 350 LCA reports within a wide range of Scandinavian manufacturing companies.

<sup>20</sup> Interview with Morten Birkholm, LCA researcher, Technical University of Denmark, 22/2 2012.

<sup>21</sup> [http://www.footprintnetwork.org/en/index.php/GFn/page/carbon\\_footprint/](http://www.footprintnetwork.org/en/index.php/GFn/page/carbon_footprint/),  
[http://www.mcdonough.com/cradle\\_to\\_cradle.htm](http://www.mcdonough.com/cradle_to_cradle.htm)



do not abide by the principles<sup>22</sup>. The Global Compact's continues to grow rapidly and now has over 8700 corporate participants and other stakeholders from over 130 countries. It is the largest voluntary corporate responsibility initiative in the world. Novozymes has been a member since 2001. For a big sustainability leader as Novozymes this is a key forum and communication channel. Additionally, Novozymes has become a participant along with 53 leading companies in UNs new platform for corporate sustainability leadership, Global Compact LEAD, launched in 2011.

Also ecolabels started by NGOs in the early 1990s<sup>23</sup> quickly became standardized. Ecolabels are based on LCA, and firms can only obtain an ecolabel if they meet certain requirements e.g. for the Nordic Swan to be among the best one third environmental performers. The requirements to achieve an ecolabel are regularly raised forcing firms to eco-innovate continuously. The last few years have seen an explosion in the numbers of different ecolabelling programs across the world and across business sectors, with many schemes broadening their issues also to cover social, ethical and safety issues<sup>24</sup>. Brand awareness of most labels (such as the EU Ecolabels) remains, however, low<sup>25</sup>. This may be seen as an indicator of low consumer demand for green products, but it could also illustrate the lack of knowledge among consumers on environmental issues. An eco-label has its limitations. It is only informative to those who already understand the green agenda. It seems the ecolabel causes more learning in firms than among consumers.

Another important trend is the rise in uptake of voluntary ecolabels and sustainability standards by the business-to-business sector. Multinational companies are taking the lead in developing standards which are global in nature and well documented. This has led to the growth of a few "super standards" which have become major global brands and are likely to edge out some of the smaller regional standards and labels in place. Key examples are the Fairtrade label, the Forest Stewardship Council for the forestry sector and the Marine Stewardship Council for fish products. These have all become well known consumer brands as well as key supplier filters for global buyers. This has led to the emergence of "standards for standards" whereby the organizations setting voluntary ecolabels adhere to guidelines laid down by wider stakeholder bodies such as the ISEAL Alliance<sup>26</sup>.

The variety of the green information standards illustrates the great many stakeholders firms have to communicate their environmental performance to. Most standards (apart from ecolabels) are directed at b2b, public purchasers, investors, insurance companies and employees and NGOs rather than directly at consumers. This illustrates well the multifaceted nature of green competitiveness of firms.

These institutions have important induced effects both within firm organizations, vertically in the value chains and horizontally in the sector. Within firms, the Danish examples show that regardless of the level of green capabilities and the initial motivation to engage in eco-innovation, firms who start on the green competitive path learn to go green. They cannot market themselves as green firms without being forced to work systematically and in-depth with environmental issues related to their products and overall firm performance. E.g. Dalum Papirfabrik initially focused on the recycling

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<sup>22</sup> [http://en.wikipedia.org/wiki/United\\_Nations\\_Global\\_Compact](http://en.wikipedia.org/wiki/United_Nations_Global_Compact), February 2012.

<sup>23</sup> Green stickers on energy use came first and have been mandated by law in North America for major appliances and automobiles already since the 1970s. see <http://en.wikipedia.org/wiki/Ecolabel#mw-head>;, January 2012

<sup>24</sup> <http://en.wikipedia.org/wiki/Ecolabel#mw-head>: January 2012

<sup>25</sup> <http://en.wikipedia.org/wiki/Ecolabel#mw-head>: January 2012

<sup>26</sup> <http://en.wikipedia.org/wiki/Ecolabel#mw-head>: January 2012

content of their green products, but soon expanded into much broader environmental perspectives through working with lifecycle assessments. Within VKR Holding they work seriously with environmental management systems and, more recently, cradle- to cradle perspectives which is renewing their green business model. Overall, today, green washing is difficult to get away with due to the high level of standardization, the high level of transparency in modern ICT based societies, and the high level of green knowledge among many stakeholders (the consumers in part excepted) especially in the affluent parts of the world, which keeps green firms on a green path. The path is not only deepening in environmental complexity (still more criteria are included in the LCA and in eco-design considerations) but in scope as the pure environmental agenda increasingly is transformed into the broader CSR (corporate social responsibility) agenda, both at business and wider strategic levels, as trends in the above institutions illustrate.

The green information institutions have important derived impacts vertically in the value chains. In the early pioneering days the less green firms functioned as bottlenecks and hence the eco-innovator saw an interest in making these more green. E.g. the communication between Dalum Papirfabrik and their less green distribution customers. Later, the more systematic integration of life cycle thinking into management systems means that firms increasingly are setting green demands on each other, especially upstream. By now green supply chain management or life cycle management is an established routine especially among the bigger companies. E.g. Novozymes vision is to ensure the right balance between better business, cleaner environment, and better lives. Their ambition is ‘to drive the world toward sustainability together with our customers and other business partners. Not alone’. They continue: ‘With our biotechnology it is possible to rethink industrial processes and lower the environmental impact throughout value chains’. For Novozymes and other of the large sustainability players it does not suffice to go green on their own. The market requires that they green other firms because of the established lifecycle paradigm<sup>27</sup>. The global companies are also important in making the eco-innovation agenda and business practices more global through their operations in numerous countries, none the least in developing countries where their (green) production or relations to suppliers are closely watched by green NGOs.

Finally, the green information institutions have important impacts horizontally. The environmental brand sticks not only to the firm but also the industry. A few environmental scandals may damage the reputation of an entire industry for a long time, as has occurred for example in the oil and chemical industry. There are therefore strong incentives for firms within the same sector to green each other. Industrial associations have, since the 1990s, at times taken on important roles in forwarding green initiatives towards their members, at other times their role has been more conserving, as they have stuck to the traditional more defensive mode, protecting their members against environmental attacks.

First Brødrene Hartmann and later Novozymes have been core innovators of derived institutional and organizational innovations for the greening of the economy in Denmark as well as internationally. It has been costly for these firms to invest in these activities, but the gain in

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<sup>27</sup> <http://www.novozymes.com/en/sustainability/sustainability-in-action/Pages/default.aspx>

legitimacy and credibility is high, compare the mentioned 15 recognitions of Novozymes as a top sustainability company. There are very high dynamic transaction costs to greening and it is clearly the big firms who have been taken the lead in developing the green market. They have the reputation need and the resources to undertake these demanding tasks. The high green dynamic transaction costs, though, functions as a barrier to smaller companies. Meeting the needs none the least of the smaller companies a range of related green service industries have emerged offering consultancy on cleaner technologies and environmental management, environmental training, green investment services, environmental insurances, environmental auditing and reporting, and so on.

While the green dynamic transaction costs were very high in the pioneering 1990s, today the level of green information standardization is all in all very high and the use of these well integrated into many business practices and capabilities or available via capable consultants. This is lowering the level of dynamic transaction costs making it easier for late coming firms and regions to enter the green market.

In the developing countries many of these green institutions are still little established. We may talk about a green divide. Eco-innovation is becoming fairly well-established in the affluent countries with well-functioning policies and market supporting institutions, while developing and in part transition economies are falling behind (Andersen 2010b).

### **Ex post –coordination – occasional coordination of complementary innovations**

The *green ex post coordination* activities consist of persuasion and teaching between firms with complementary innovations when they find that their innovation has become incompatible with other players in the value chain. In the case of eco-innovations the need to coordinate complementary innovations in the value chain is especially high in connection to recycling innovations. E.g. in the case of Dalum Papirfabrik paper recycling, the product innovation was difficult and required demanding interfirm coordination, as the product to some degree initially was incompatible with a range of complementary products such as copy machines and printers on the user side and ink and glue on the input side (via the waste paper). Problems with glue (from envelopes) and inks which were difficult to remove from the waste paper led Dalum to engage in dialogues with producers of these but with no results. The failure of these coordination attempts meant that Dalum had to invest further in their waste paper pulp preparation facility to be able to deal with the impurities in the waste paper. Any product innovation along the paper chain will affect the quality of the waste paper which therefore is a transitory raw material. The problems noticeably with glue caused problems in the copy machines and printers which were solved to a reasonable degree, a process which included dialogues with these producers. Additionally wholesalers, retailers and end users were skeptical as to the product quality so dialogues, teaching of customers and communication campaigns towards end users were important for a long time.

While ex post coordination normally receives attention because it may lead to vertical integration (see e.g.(Langlois 1992,2004; Teece 2010), the point here is that often it may not; it may rather lead to intense negotiations between firms, and hence learning through adaptation, also in the case of unsuccessful coordination activities. E.g. the firms addressed by the recycling company may not initially have changed their ways of production, but they have become more aware and knowledgeable about recycling needs and concerns.

The distinction between ex ante and ex post coordination is important because it emphasizes the time element in the firm-market coordination. If firms invest sufficiently in ex ante coordination with well developed relational assets and standardized interfaces with the other players in the chain, they may reduce the need for ex post coordination, as they make it more likely that their strategies and innovations are on the same ‘wavelength’ as these other firms. Today, in the era of the information society, the costs of ex ante coordination are lowering, firms and markets are more transparent. This may reduce the need for ex post coordination as relations between firms generally are becoming more cooperative. This is fertile ground for the greening of the economy.

### **Green knowledge cooperation**

The *green knowledge cooperation* represents the knowledge migration between firms horizontally and vertically, related to their green technical but also managerial (green business models) capability building. The close knowledge collaboration as part of firms’ R&D is a core means of gaining shared green search rules and an assimilation of green capabilities.

The paper industry is known to be a supplier dominated industry and relies heavily on cooperation with its big chemical and machine suppliers for their R&D. E.g. Grenaa Papir were cooperating closely with their suppliers in developing the ‘kidney’ that allowed them to close their water system and which necessitated adjustments of the entire paper production process. Testing and experiments were carried out on the facilities of the chemical suppliers. The suppliers had experience with similar systems but used in other sectors which they could transfer. As the chemical industry were among the most scolded industries for being ‘ungreen’ with their often highly toxic products, these companies were eager to develop a more green profile and green capabilities were early active in eco-innovative activities.

Similar, the VKR Holding window company also relies to a high degree on cooperation with their big suppliers, who are more important learning partners than universities. They have e.g. engaged in cooperation with metal suppliers on more environmentally friendly metal coatings and with the paint producers for more enduring and environmentally friendly paint. They have ongoing dialogues with the big glass producers on glass R&D, via their own glass R&D department, as the selection of the right glass is a key competitive factor to VKR.

The high importance of green R&D between users and producers have also been found in other studies (e.g. Simpson and Samson, 2007; Bossing, 2007). A recent Spanish quantitative study concludes that eco-innovative firms cooperate with external partners to a higher degree than other innovators, especially with suppliers, while cooperation with clients is not differentially important (Di Marchi, 2011).

Also horizontally, firms engage to some degree in formal and informal knowledge cooperation. There are indications that firms are more willing to share their eco-innovations with other firms than is the case for ‘normal’ innovations, at least when it comes to innovations which are less unique to the company's core competencies. E.g. Grenaa Papir gained insights on water recycling from one of their competitors, and similar expressed that they had passed on information on their new water system to competitors as they thought that the eco-innovations should be widely diffused. The big suppliers with generic capabilities such as the chemical and in part machine

industries act as important transferers of green capabilities and eco-innovations between the different sectors they feed into.

Formalizing, and marketing, this more some of the big companies such as Nike, Best Buy and Creative Commons launched the GreenXChange in 2010, an organization dedicated to sharing green patents allowing companies working on innovation in sustainability 'to share research in a way that's legal, safe and potentially profitable'<sup>28</sup>. This and similar activities should be seen in relation to increasing demands from developing countries in UN ongoing climate negotiations for the rich countries and big companies to share their knowhow on eco-innovation with developing countries (UNEP, 2011; United Nations, 2011). As a direct consequence of this the European Patent Office began developing a new classification scheme for 'green patents' in 2010. The pressure on big companies to behave responsible to achieve a license to operate seems to continue to go up.

### **Towards a green trajectory and a green business model**

The argument in this paper is that the combined sum of the three types of firm interaction processes described above means that firms make each other go green as a part of the economic process. The empirical findings clearly illustrate the extensive amount of dialogues, coordination and hence adaptive learning as well as deliberate learning activities between firms on environmental issues. Via these processes knowledge and strategy assimilation takes place between firms interacting in multiple ways. At the knowledge level a shared underlying green trajectory is evolving, as a new resource efficient pattern of problem solving activity are replacing the old wasteful one. At the strategic level a new green business model is emerging, where the environment and increasingly CSR is a business case to stay, though a demanding and difficult one. Induced and related innovations horizontally and especially vertically means that expansionary processes are setting in as more and more industries are pulled into the green economic process.

The interactive creative processes described give rise to considerable organizational and institutional changes within and especially between firms as well as towards other stakeholders, entailing green economic evolution reducing the initially very high dynamic transaction costs to greening.

## **6. Into the green economy - towards a model of green economic evolution**

An interesting question related to the rise of the greening of the economy is why we see a breakthrough in the 1990s and again and acceleration at the end of the 2000s. Following 50 years of environmental regulation with practically no sign of green economic change, why do things start to change in the 1990s? Expanding on the model of Perez (1983, 1985) and Freeman and Louca (2001) some speculative explanations are forwarded in the following, realizing that, partly, the empirical evidence of the greening of the economy is somewhat poor, and that partly, much may still happen in the ongoing greening of the economy, taking the development into quite other directions.

The initial greening factor is the mismatches between the environmental part of the political system and the economic system which meant that still stricter environmental policies were targeted directly at companies. Unresolved environmental problems following 60 years of environmental

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<sup>28</sup> <http://www.greenxchange.cc/> accessed February 2012.

policies meant that both policymakers and business were looking for new cooperative solutions to this conflict-ridden situation.

At the same time underlying changes in competitive conditions of the knowledge economy begin to play a role. The intense global competition in still more affluent countries (such as Denmark) meant that competition increasingly is on other issues than costs (Lundvall, 2007). With ICT the transparency of markets and the knowledge levels of stakeholders on firms and products grow rapidly. In this setting the rise of the big and visible firm leads to new strong needs for branding. The rising tension between big firms and green NGOs and environmental authorities is a key explanation for the emergence of the environment as a business case.

The high information costs and systemic features of eco-innovations are core explanations for the diffusion patterns. The uneven distribution of green strategies and capabilities has meant that firms have had to make each other go green as part of the economic process. It is the big firm who have had the resources and the needs to pull in the complementary assets required to create the green markets. They are essential actors in the early development of the demanding institutions and organizational changes which have been necessary in the green economic process. Their active presence explains the rapid greening we have experienced particularly the last five years.

The wider diffusion of green markets and technologies has taken place in creative, interactive processes between companies, with information standards playing a key role; not only in facilitating market creation but as enablers of learning and innovation. As such their effect has been marked and pervasive and appears to keep firms on a still stricter green but transitory path.

Fertile ground for the diffusion of eco-innovation has been found among the heavy polluting industries who had been subjected to environmental policies sufficiently long (50-60 years) for considerable green learning to have taken place and therefore, paradoxically, function as carrier industries for the greening of the economy. The same goes for the much scolded (by environmental researchers and NGOs) End of Pipe sector, which functions as important sources of green knowledge to a range of industries. Adding to Peres framework and the innovation system framework is the emphasis on the slow accumulation and assimilation of green knowledge and strategies at the firm level, as the firm learns continuously with its selection environment; first of all other firms but also influenced by research in knowledge institutions. Developments in underlying environmental and sustainability research led to new insights into the role of companies and products for environmental degradation, and methods for assessing alternative green product strategies. The evolution of a distinct generic green trajectory is a key explanation for the pervasive paradigmatic effect of green economic change.

A milestone in the greening of the economy, not yet addressed, was the demonstration of profitability, compare (Freeman, Clark and Soete, 1982). This was lacking, largely due to the lock-in into the 'environment as a burden to business' rationale. Profitability was demonstrated not on the market, where it was not yet present or documented, but via the reframing of the environmental business agenda. The formulation of the vision of the 'environment as a business case' is a milestone. This new agenda was created by the new Business Council for Sustainable Development developed in 1990 consisting of some of the largest companies to be the business voice at the UN Earth Summit in 1992 in Rio. Further publications and activities by this organization, (since 1995

known as the World Business Council for Sustainable Development) have been decisive for the establishment of the green growth agenda<sup>29</sup>. Changes at the policy level is also important, as the green growth agenda only took of as the first ministries of industry and innovation, EU and OECD began to formulate such strategies emerging at the end of the 1990s to escalate more in the second half of the 2000s and end, so far, with the formulation of the green economy agenda around 2009-2010 (Andersen, 2004, 2009; OECD, 2010, 2011)

The greening of the economy at the micro-level is very much a story of emerging firm greening. It is the gradual realization of green profit opportunities in the firm-market uneven greening process. Some of these opportunities have been readily available to the companies but have not been utilized; others have required much more effort to be harvested. Those firms who happen to operate in value chains and markets where the green dynamic transaction costs are low and the green appeal is high are those who are early movers in the green economic evolution. We still need more studies to identify the properties of these firms, sectors and chains as this has been neglected by research so far.

Despite the normative appeal to greening, being 'good', the green economic change has been surprisingly conflict-ridden, as early eco-innovators have had to overcome the considerable well-established skepticism towards the green profit opportunities. Only the last 3-5 years have seen a wider recognition of the environment as a business case and hence firms swarming in to seize the green profit opportunities, which are finally more widely recognized. As the costs to greening are sinking as market institutions and capabilities become still more established this process is likely to expand and pick of further pace.

## 9. Conclusions

The theme of the greening of the economy is of considerably interest because it sheds light on the fundamental social and economic difficulties and the longevity of changing direction in technology. This paper has sought to highlight core dynamics of the greening of the economy from an evolutionary economic perspective, arguing that green economic change represents one of the most profound examples of economic change. The ongoing greening of the economy is clearly demonstrating that externalities are not given and public-private domains are shifting as firms are engaging in new types of more responsible innovations. The latter sounds as a very conscious, deliberate corporate strategic shift. But firm greening, this paper proposes, has rather been of a very emerging character, evolving gradually, in part tacitly, through multiple, related processes.

Defining the greening of the economy as a techno-economic paradigm change the paper has suggested expanding on Perez's and Freeman-Louca's frameworks of such paradigmatic changes. Rather than focusing on tensions and mismatches at the macro level, the paper proposed to emphasize the changes taking place at the micro firm and especially interfirm level. The neglected ongoing learning and institution creation taking place between firms in the economic process is suggested as a central dynamo of economic evolution. The paper forwards an evolutionary capabilities approach in seeking to explain when and where such processes take place and hence important determinants in directing economic evolution.

While paradigmatic changes are often seen as induced by a technological 'key factor', the greening of the economy presents a special case. It is rather the evolution of a new green trajectory of eco-

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<sup>29</sup> See further at <http://www.wbcsd.org/home.aspx>, Fussler and Clark, 1996, WBCSD, 2000

efficient problem solving, as well as new green selection criteria on the market. These, the paper argues, evolve to a large degree as part of interactive, creative economic processes between firms. More specifically they are the sum of three interrelated processes. Ongoing (ex ante) coordination, conflictual (ex post) coordination as well as deliberate knowledge cooperation. These are suggested as central mechanisms of (green) economic change.

Specific features of eco-innovation influence on the green economic change. Eco-innovation is associated with major organizational and institutional failures related to high information problems and systemic features. Firms, it is argued, have to make each other go green as part of the economic process. This deliberate greening involves particularly the ongoing ex ante coordination, which is important as it leads to the creation of a series of still more elaborate green information standards which have major induced effects on the greening of firms. Furthermore, the paper has argued that the big firms, originally the green villains, have been important in pulling in the complementary assets necessary for the greening of the economy. Over time, the dynamic transaction cost to greening sinks as the green market and the underlying green trajectory matures. In the current stage of rapid green market growth the initial very uneven distribution of green strategies and capabilities is leveling out somewhat, bringing firms on a more similar 'green wavelength', drastically reducing the green dynamic transaction costs. The economy and technology increasingly moves in a green direction. The notion of 'green', however, undergoes change continuously under way. Hence we know little about what this green direction more specifically entails, apart from the general condition that production and consumption factors are becoming more resource efficient and that firms integrate environmental concerns into their business practices still more.

The evolutionary perspective forwarded here is in stark contrast to more absolute and normative perspectives of environmental sustainability within environmental research and policy making. The evolutionary perspective emphasize that incremental eco-innovations may induce other more radical and systemic innovations. Viewing the firm not as polluter but as a potential eco-innovator opens up for a radical redefinition of firms' and sectors' role in the eco-innovation processes. All firms and sectors play a role for eco-innovation, though the roles of different sectors and types of firms are hitherto little understood. There is a need for more research into the industrial dynamics of the greening of industry, so we may know more about who the leaders and the laggards of the green economic evolution are and how to provide better incentives for eco-innovation for different types of firms and sectors.

The greening of the economy reflects important features of modern economic complex systems, leading to a much broader, value-based notion of innovation. Some wider structural change of the economic system seems also already visible. Markets appear to become more connected (specific) via the demanding green economic change process; markets are also becoming more transparent with higher information and learning needs. The organization of production (and consumption) is becoming more interdependent and complex as we shift from linear to circular resource flows in the production and consumption systems (a shift which we are only seeing the beginning contours of now). Overall, the green economy is characterized by high knowledge and coordination demands and could not have come about without the rise of the knowledge economy.

The greening of the economy is a very complex historic case. Many more factors could have been brought in, such as more attention to changes in the rationales and power, of environmental



policy over time, power struggles between ministries, the changing role of NGOs, important new understandings emerging from different research areas, including heterodox economic understandings, and so forth. Many more important mismatches could have been pointed to. Still, the focus on the firm and interfirm level, it is here argued, does capture central and neglected elements in the ongoing greening of the economy.

The evolutionary economic perspective presents important insights in the greening of the economy and may even have contributed to it<sup>30</sup>. It also has some limitations towards the greening of industry and the economy. Wider societal changes and none the least changes in consumer practices go beyond this framework. Also, while evolutionary economics argues that it is long run economics, the long run is not long enough to address the very long run necessary to understand environmental sustainability. This may lead to considerations about the limitations in economic theory altogether towards this issue.

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<sup>30</sup> The strategy paper I wrote with Rene Kemp, on eco-innovation policy for the informal EU council meeting in 2004 had an important role in setting eco-innovation high on the EU agenda for the first time, contributing to the uptake of this agenda by European countries and later the OECD and UN see (Kemp and Andersen, 2004, Kemp, Andersen and Butter, 2004).

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