

Merging Research Perspectives on Innovation Systems and Environmental Innovation: An Introduction

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This book is about innovation systems and the possibilities and limitations of shaping their evolution and transformation. It is also about innovation and the environment, or, perhaps more precisely, innovations and sustainability. As such, it addresses the question of the direction of innovative activities in social systems. It is widely recognised nowadays that giving innovation a direction that takes it *beyond the contribution it can make to economic growth* represents a major challenge for modern societies, a challenge that requires more than technological innovations. In addition, major changes are required along the entire production consumption chain, its flows, its multi-level architecture, its institutions and structures, and – not least – the behaviour of the actors involved in it, from resource extraction to the final consumption of goods and services. Innovation systems are thus required to deliver a new quality of outcomes. This new quality can be captured by the term environmental system innovations, which can be defined by five characteristics: functional changes with a jump in eco-efficiency; a combination of technological, organisational and institutional innovations; the involvement of a multitude of actors; the existence of new guiding principles and sets of goals; and long-term changes at micro- and meso-level (Butter 2002). Innovation systems expected to generate environmental system innovations require new policies and governance approaches operating at and coordinating between different levels and realms of policy-making.

The objective of this book is to contribute to the shaping of a multi-disciplinary research field that helps address these policy challenges. Over the last decade two main streams of research work have emerged that are of major relevance to this issue. First of all, the work on national, regional and sectoral systems of innovation, based mainly on an evolutionary perspective of technological change, has widened the spectrum of innovation determinants that are regarded as relevant. Institutional and organisational frameworks, cumulative learning processes between users and producers and the importance of spatial and technological characteristics are now regarded as indispensable elements in innovation research (Lundvall 1992; Nelson 1993; Braczyk et al. 1997; Edquist 1997; Malerba 2002). However, most research work in this tradition has concentrated on the economic consequences of innovation and hardly taken environmental considerations into account.

Secondly, research work on the impact of environmental regulation on innovation emerging in environmental economics has been a major building block in

closing this gap (i.e. Hemmelskamp, Rennings & Leone 2000; Licht et al. 1995; Kemp 1994; Green et al. 1994). Considering environmental regulations as push and pull factors and thus as part of a comprehensive system of framework conditions influencing innovation, this research has broadened the debate on the dynamic effects of environmental policy instruments. By combining elements of innovation research, environmental economics and policy analysis a new, applied perspective on environmental innovation has emerged. It improves our understanding of the impact of environmental regulation on innovation behaviour and provides an analytical framework for explaining the first-mover hypothesis. Subsequently, new policy models like transition management, lead market concepts or time strategies for policy actions were developed that strongly influence current debates about policy for innovation and the environment.

While both streams provide complementary insights into innovation processes in systems, technological change and their potential for improving the environment, little interaction has taken place between the two in terms of building a common conceptual and theoretical framework. This is not to say that no research work had been conducted at the interface between the two streams of research. But there are few forums where this interaction has been deepened.

Since the end of the nineties, however, the linkages between innovation and the environment have become a major issue in national and international research programmes. Moreover, the focus on environmental aspects has been broadened by taking sustainability as an overarching frame of reference. For instance, in 2000, a new research programme was initiated by the German Federal Ministry of Education and Research (BMBF) that aims to advance our knowledge about the role of “framework conditions for innovations towards sustainability (RIW)”. It builds on a preceding programme dealing with innovation and the environment (Klemmer 2000) but its scope is broader in that it also includes other dimensions of sustainability beyond the environmental. Merging the two aforementioned streams of research is regarded as a promising approach to providing a theoretical and conceptual foundation for a better understanding of the role of framework conditions for innovations towards sustainability and in particular the possibilities of inducing system innovations by means of policy.

This interest in system innovations for sustainability is shared by research communities in several other countries and corresponding research programmes have been implemented that deal with innovation, the environment and sustainability. For instance, the concept of transition management has become very influential in the Netherlands as a guiding framework for informing policy-makers about long-term strategies for system transformations towards sustainability (Rotmans et al. 2001). At a European level, both within the Fifth and the Sixth Framework Programme, sustainability and innovation has become a major research issue (CEC 2002).

Therefore, one of the aspirations of this book is to bring the research communities from different disciplines and countries together and enable an exchange of experience and a review of the frameworks used to guide research and policy “towards environmental innovation systems”. It brings together a selection of contributions exploring new directions of work at the borderline between innova-

tion systems and environmental innovations research. It comprises empirical and conceptual as well as policy-oriented contributions. It is structured along the lines of four main areas of interest with respect to environmental innovation systems: conceptual foundations, empirical experiences, strategic approaches and experience with policy instruments. Accordingly, the first part of the book brings together contributions with a conceptual and ground-laying research interest, dealing in the first instance with key concepts and approaches that promise to represent a useful foundation for thinking about system innovations geared towards sustainability and in particular towards improving the environment.

In his article, Paolo Saviotti discusses one of the fundamental relationships underpinning the transformation of innovation systems towards sustainability, namely the co-evolution of technologies and institutions. After introducing some basic interpretations of the term co-evolution, as well as its use in economics, he shows how institutions and technologies have co-evolved in the past, taking motor vehicles and biotechnology as examples. These illustrations then serve to elaborate some generalised hypotheses about the co-evolution of technologies and institutions – including a taxonomy of institutions – and the extent to which there is scope for inducing innovation by means of introducing “appropriate” institutional changes. This brings him finally to discuss the “win-win” argument that is often applied with respect to environmental innovations, i.e. the hypothesis that innovation can be beneficial to both the innovating firm and the environment. He suggests that while it may apply in selected cases, it is – to say the least – very difficult to disentangle whether the net environmental effect is positive or outweighed by second-order effects that may occur. For instance, efficiency-enhancing technologies may well induce demand effects that over-compensate the direct efficiency gains achieved. As a consequence, designing appropriate institutions to induce technological innovations for improving on the (co-evolving) environment is an extremely challenging task which needs to be informed by further work on the co-evolution of technology, institutions and the environment.

System innovation offers a route for achieving sustainability benefits. This requires the management of evolution processes and the orientation of private and public actors to transition goals. New policy concepts and instruments are therefore needed. Transition management attempts to gear existing dynamics to transition goals chosen by society. Through its focus on long term goals of sustainability and its attention to dynamics it aims at overcoming the conflict between long-term ambition and short-term concerns. In the article by Rene Kemp and Jan Rotmans, transition management is described and exemplified in connection with a low-emission energy supply system.

Frans Berkhout’s contribution addresses the core issue of this book, namely system-level changes that promise to bring about significant reductions in environmental impacts. Using the concept of regime shifts, he is interested in the question of whether and how such regime shifts could be induced and in particular what role they might (or might not) play in contributing to such an inducement. More specifically, he examines evidence on the question of whether environmental pressure does indeed have an impact on the rate and direction of technical change, and if so, whether more environmentally friendly technology trajectories

or regimes can be expected to inform policy. By looking at two rigid PVC products used for construction purposes and at coated printing and writing paper, he identifies three main interdependent channels through which environmental pressure exerts an influence on innovation: product design, process changes and abatement technology. In both cases, a sudden reversal at the regime level was observed, rather than a smooth transformation and bottom-up improvement of the incumbent technological regime. In this respect, he differs from the proponents of transition management who favour a “soft” transformation approach to achieving a regime shift. This has important implications for policy. Key factors in inducing a regime shift are, in his view, competition and the encouragement of new incipient regimes, rather than complicated adjustments of the dominant regime.

The second part of the book contains a selection of empirical case studies based on a combination of an innovation systems perspective and a keen interest in the transformation of these systems to achieve higher environmental performance. National, regional and sectoral perspectives are brought together.

Halina Brown discusses the transformation of the Polish industry and innovation system that brought about a significant improvement in environmental quality during the 1990s. Evidence of these improvements is given by drawing upon different indicators of environmental performance. The modernisation of the regulatory system is recognised as one of the key factors that contributed to this success story. The strengths of the regulatory system are traced back to a high degree of continuity in institutions, policies and modes of societal transaction, to widely shared values and attitudes among the key societal actors and to a broad support for the rule of law and due process. In other words, a culture of compliance was successfully established. For the future, the ability of the Polish innovation systems to generate technology and system innovations that allow for a reduction of the environmental intensity of production and consumption is seen as crucial in coping with the consequences of current economic growth, especially as Poland is not performing particularly well in terms of innovation.

Gerd Schienstock addresses the issue of innovation systems and sustainable development from a regional perspective. He argues that the changing nature of innovation processes, reflected in the greater emphasis now being placed on tacit knowledge and informal cooperation, strengthens the importance of the spatial vicinity of the actors involved in networked innovation processes. Integrated environmental technologies represent a new development pathway to which regional policy can contribute, for instance by shaping appropriate *Leitbilder* and by acting as a facilitator of regional cooperation for sustainability-oriented innovation.

Based on six case studies of the Scandinavian energy system, Atle Midttun and Anne Louise Koefoed deal with the dynamics of innovation and discuss the interplay between processes within a broad set of institutional contexts, ranging from politics to markets, and their importance for successful innovation.

Frank Becker and Frank Englmann investigate the role of public policy and voluntary initiatives for promoting water-benign process innovations in the chemical industry. In an empirical analysis they analysed the West German chemical industry during the mid-1990s. Their results show that compliance with environmental regulations seems to have been by far the most important reason for

implementing both end-of-pipe and integrated environmental innovations. These findings are of particular interest with respect to the implementation of the new EU Water Framework Directive and also for EU chemicals policy.

The third part of the book focuses on future strategies favouring the move towards environmental innovation systems.

Nicolas Ashford challenges certain tenets of the theories of reflexive law and ecological modernization. While far-sighted prevention-oriented and structural changes are needed, some proponents of these theories argue that the very industries and firms that create environmental problems can be transformed - through continuous institutional learning, the application of life-cycle analysis, dialogue and networking with stakeholders and the implementation of environmental management systems - into sustainable industries and firms. However, while useful, these improvements are inadequate. It is not marginal or incremental changes that are needed for sustainability but rather major product, process and system innovations - which are often beyond the capacity of the dominant firms and industries. Ashford also questions the alleged failure of regulation to stimulate necessary technological changes and identifies the conditions under which innovation for sustainability can occur. Finally, he discusses differences in policies for innovation and the environment in industrialized and developing countries.

A national lead market is often the geographical starting point for a global diffusion of products or processes. Lead markets for environmental technologies also depend on various kinds of policy action. Martin Jänicke and Klaus Jacob discuss the potential role of lead markets in the context of global economic modernisation. In particular, they go into the interplay between the diffusion of environmental policy innovation and environmental technology.

Georg Erdmann's article focuses on the time-dependence of innovation pathways and the fact that solutions to a current problem may represent the problems of the future. As a consequence, he argues that sustainability should be understood as a continuous process rather than as a stable end-state. Moreover, critical factors for the success of a specific instance of innovation are not just its inherent characteristics but also whether it emerges at a time when it can benefit from reinforcing effects such as economies of scale, learning and network effects or specific regulatory conditions. There are windows of opportunity when innovations have a high success probability, while at other points in time they may be of negligible importance. He underpins his argument by discussing the example of how different chlorine production technologies have spread in Europe and Japan, showing that Japanese technology policy applied an appropriate time strategy for establishing an advanced technology in the chemical industry, whereas European regulation was rather counterproductive by imposing rigid emission standards too early on, thus preventing a superior technology from establishing itself once it became available. In his article, Erdmann points to some general lessons to be learned for innovation (and diffusion) policy, based on his insights on time strategies for policy intervention.

Remco Hoogma, Matthias Weber and Boelie Elzen present one possible approach to the induction and management of transition processes towards sustainable innovation systems. This approach is based on bottom-up processes of niche

development that can potentially shift the dominant technological regime. Past examples of how regime shifts have occurred are used to illustrate the momentum that small niches can develop. Strategic niche management is suggested as a kind of modulation policy capable of inducing regime shifts. They pay particular attention to the role of niche managers, i.e. companies or public authorities that take a lead function in the niche development process.

Nigel Roome argues that the real challenge is to develop a form of continuous iteration between the policy framework and the demands of local environmental and specific socio-technical systems. He develops a conceptual model of the transition from innovation in environmental compliance-driven industry to innovation in more sustainable forms of enterprise. Proceeding from this model, he describes principles and processes as key elements of a “design guide for sufficiency” which is the outcome of the EC Expert Group on “Policies and Actions for Sustainable and Competitive European Production Systems”. Finally, Nigel Roome formulates key points for policies and conditions for innovation improving competitiveness within the framework of sustainability.

The fourth and final part of the book deals with the assessment of recent policy initiatives aimed at improving the integration of environmental considerations in technology and innovation policy. On this basis, new requirements for policy and research are derived.

Yukiko Fukasaku discusses the particularities of environmental innovation, the issues the policy makers need to address in designing effective environmental policies and research and innovation policies that optimise environmental innovation. She discusses the specific information needs of policy makers enabling them to contribute to optimising environmental innovations. Fukasaku demands information on public and business expenditure in environmental R&D and on how and where the funds are spent. She also demands better knowledge about the determinants of environmental innovations in firms, how firms assess the costs and benefits involved and how they can acquire relevant information.

Vicki Norberg-Bohm and Theo de Bruijn concentrate on the emergence processes characteristic of policy innovations within the context of environmental innovation systems. Drawing on new institutional theory and the literature on technology policy and management, they discuss the role of voluntary, collaborative and information-based strategies in technological innovation. They compare three U.S. programs to three Dutch programs and investigate why comparable approaches are successful in one context and fail in another. They also recommend ways in which policy innovation can either work within or change the existing regulatory structure.

The IPPC Directive lays down a framework requiring EU member states to issue operating permits that contain conditions based on best available techniques (BAT). It requires the European Commission to organize an exchange of information between member states and the industries concerned with best available techniques. David Hitches, Frank Farrell, Josefina Lindblom and Ursula Triebswetter discuss the impact of the implementation of BAT on the competitiveness of existing plants. Focusing on three industries, the paper answers various questions: Are BAT plants viable? Do they suffer disadvantages in the face of international com-

petition? What are the implications for the economic viability of the sectors concerned? The principal methodology adopted is a case study approach contrasting the economic performance of plants that have adopted most of the elements of BAT with the performance of other 'non-BAT' plants in the various industries.

In the attempt to achieve system innovation, Philip Vergragt recommends that the role of the government should be to formulate and legitimise the direction to be taken in connection with sustainable development. He describes the concept of back-casting and reviews the important "Dutch Sustainable Technological Development" program and the "Strategies towards the Sustainable Household" project. In particular, he reflects on the role of government, business and societal actors in transitions and system innovations.

Finally, Ken Green gives a synthesis of the outlook on issues for the future. Building on his assessment of emerging key challenges to achieving the shift from 'environmental' towards 'sustainability' innovation policy, he identifies both new research needs and policy requirements. In particular, finding the right division of labour between national, sub-national and supra-national entities with respect to the evolutionary process of innovation for sustainability is seen as a crucial issue for the future.