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ESCAPING PATH DEPENDENCE – ESSAYS ON FORESIGHT AND ENVIRONMENTAL MANAGEMENT

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Title: Escaping Path Dependence – Essays on Foresight and Environmental Management

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Abstract: The dissertation examines linkages between foresight, innovation and environmental management and policy to escape undesirable path dependencies at the different levels of innovation systems, especially with the means of foresight. The dissertation is characterized as action research that applies literature reviews, semi-structured interviews, direct observations, Internet-based group support systems, decision analysis, trend analysis and computer assisted workshops within case studies and empirically grounded theory-building.

The dissertation consists of six articles and the summary. The first article deals with responsiveness in the management of foresight activities. The second article studies possible ways to escape techno-institutional path dependencies by combining methods used in foresight activities and drafting environmental voluntary agreements. The third article applies this approach to the analysis of a hydrogen energy foresight. The fourth article examines how environmental management systems may strengthen path dependencies. The fifth article develops and applies a new foresight method RPM Screening, which is also applied in the sixth article in connection with a European coordination tool.

The implications of the mechanisms of path dependence on foresight objectives are identified as follows: (i) improved systems understanding calls for attention to continuous and discontinuous changes, which can be facilitated by diversity considerations, (ii) enhanced networking requires not only strengthening existing networks but also restructuring or even destruction of possible lock-in conditions by a redefinition of stakeholder roles and (iii) strengthened innovation activities necessitate fostering prospective innovation ideas, rivaling coalitions and the development of new technological and institutional arrangements. The results of this dissertation suggest extending the locus of foresight processes closer to decision-making and conducting them in connection with other coordination-oriented policy tools to address also institutional arrangements for discontinuous systemic changes. Whereas the dissertation identifies and responds to these challenges by developing responsive and modular foresight methods, further policy experimentation is recommended to support policy learning and the collection of further evidence for the findings.

Keywords: foresight, environmental management, group decision-making, innovation policy, path dependence.

Academic dissertation

Systems Analysis Laboratory
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Escaping Path Dependence – Essays on Foresight and Environmental Management

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	Professor Pablo del Río González, University of Castilla – La Mancha, Spain
Official opponent:	Professor Ruud Smits, Utrecht University, The Netherlands

Publications

The doctoral thesis consists of the present summary article and the following papers:

[I] Salo, A., Könnölä, T. and Hjelt, M. (2004). Responsiveness in Foresight Management: Reflections from the Finnish Food and Drink Industry, International Journal of Foresight and Innovation Policy 1 (1-2), 70-88.

[II] Könnölä, T., Unruh, G.C. and Carrillo-Hermosilla, J. (forthcoming). Prospective Voluntary Agreements for Escaping Carbon Lock-in. Journal of Ecological Economics 57, 239-252.

[III] Könnölä, T., Unruh, G.C. and Carrillo-Hermosilla, J. (forthcoming). Toward Prospective Voluntary Agreements: Reflections from a Hydrogen Foresight Project, Journal of Cleaner Production.

[IV] Könnölä, T. and Unruh, G.C. (forthcoming). Really Changing the Course: The Limitations of Environmental Management Systems for Innovation, Journal of Business Strategy and the Environment.

[V] Könnölä, T., Brummer, V. and Salo, A. (2006). Diversity in Foresight: Insights from Fostering Innovation Ideas, Helsinki University of Technology, Systems Analysis Laboratory, Research Report E19.

[VI] Könnölä, T., Salo, A. and Brummer, V. (forthcoming). Foresight in European Coordination: Developing National Priorities for the Forest-Based Sector Technology Platform, International Journal of Technology Management, special issue on technology foresight.

Contributions of the author

The six papers were initiated by Könnölä, who was the primary author of all but the first paper.

Paper (1) is based on the project in which Könnölä worked as an expert and participated in the process management together with the other authors. Writing the paper was a collaborative effort initiated by Könnölä. He contributed to the development of the approach and wrote the first drafts that were taken further by Salo and Hjelt.

In paper (2), Könnölä identified linkages between different research areas and elaborated a new policy tool for responding to the challenges identified within the conceptual framework that was originally developed by Unruh. Unruh and Carrillo-Hermosilla participated in the elaboration of the paper towards the journal submission.

In paper (3), Könnölä initiated the work to elaborate the approach described in paper (2) and applied the approach in a new policy context. Unruh participated in the elaboration of the paper and Carrillo-Hermosilla commented on the paper.

Paper (4) was initiated by Könnölä, who extended and elaborated the theoretical framework developed by Unruh and applied the approach to the analyses of an empirical phenomenon. Developing the final version of the paper was a joint effort.

Paper (5) is based on the research project in which Könnölä worked as a researcher and participated in the process management together with the other authors. He wrote the first drafts that were further elaborated by Brummer and Salo.

Paper (6) is based on the research project in which Könnölä worked as the project manager and participated in the process coordination with the other authors. He contributed to the development of the approach and wrote the first drafts that were finalised through joint efforts with Salo and Brummer.

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Totti Könnölä

1. Introduction

In the 1980's, publicly funded foresight activities were largely seen as an instrument for assisting in the development of priorities for S&T resource allocation (Irvine & Martin, 1984). Later on, stakeholder participation and networking have been regarded as increasingly essential dimensions of foresight activities for 'wiring up' the multi-layered innovation systems both in public (Martin & Johnston, 1999) and private sector (e.g. Salmenkaita & Salo, 2004). Reports from recent participatory foresights, in turn, have emphasized the importance of common vision-building as a step towards the synchronization of the science, technology and innovation system (innovation system, for brevity) (Cuhls, 2003). In these developments, the locus of foresight activities has tended to shift from positivist and rationalist technology-focused approaches towards the recognition of broader concerns that encompass the entire innovation system, including its societal dimensions such as challenges of sustainable development. The High Level Expert Group appointed by the European Commission crystallized these trends by defining foresight as follows (European Commission, 2002): "A systematic, participatory, future intelligence gathering and medium-to-long-term vision-building process aimed at present-day decisions and mobilising joint action". While the expansion of foresight scope has provided significant opportunities for learning and synchronized action between different policy fields, it may also have caused digression and ambiguity in the practice and theory of foresight management (Salo & Cuhls, 2003). This dissertation responds to this challenge by examining foresight management in view of innovation and environmental policy and management.

In search for coherent theoretical premises for foresight management, the dissertation builds particularly on the literature of evolutionary economics (e.g. Dosi et al, 1988; Nelson & Winter, 2002) and perspectives on path dependence in the co-evolution of technological and institutional systems. Path dependence refers to that directions for future development are foreclosed or inhibited by directions in past development (see e.g. Mahoney, 2000), as most innovations build off of past discoveries and need to adapt to pre-existing conditions for successful diffusion. While the debate on the validity of the historical ex post cases continues (David, 1985, 1989; Arthur, 1989, 1994; Liebowitz & Margolis, 1995; Mahoney, 2000), the main value of the concept of path dependence is rather in the identification of the mechanisms of path dependence at the different levels of innovation systems. This has encouraged the elaboration of interdisciplinary approaches to understand major challenges both in innovation (Lundvall, 1992; Edqvist, 1997) and environmental management and policy (Jacobsson & Johnson, 2000; Unruh, 2000; Kline, 2001; Frenken et al., 2004). Even though such efforts have helped understand unfavourable path dependencies and

lock-ins, they have offered little support how to avoid and escape from such conditions (Garud & Karnøe, 2001; Unruh, 2002). Within this discussion, the dissertation explores linkages between the literature on path dependence and foresight and environmental/innovation management and policy. This may provide basis for concerted policy and management efforts to understand and escape from existing lock-in conditions that delay or even inhibit innovation processes crucial for moving toward sustainable development. The novelty of the dissertation lies in the development of coherent multidisciplinary foresight management approaches with practical value in coordination-oriented innovation and environmental policy. In particular, the dissertation documents collected experiences from conducted foresight processes and empirically based theory building which supports the development of a novel foresight methodology that combine analytic and communicative methods.

Section 2 positions the dissertation in the literature within the chosen theoretical groundings. Section 3 deals with the methodology of the dissertation, and Section 4 describes the results, which are discussed in Section 5.

2 Theoretical Premises

The management of foresight activities draws upon a large range of different disciplines such as evolutionary economics and technological change theories, systems analysis and operations research, sociology and political sciences, actor-network and communication theories, organizational change and knowledge management, among others. However, the effective deployment of different disciplines in the foresight management calls for a coherent theoretical framework. For this dissertation, the tradition of evolutionary economics and technological change (Dosi et al., 1988, Nelson & Winter, 2002) provides the basis that (i) acknowledges technology as an endogenous phenomenon within the economy and (ii) characterizes the technology as knowledge, of which the creation and exploitation is highly dependent on available resources including various capabilities and time. Fundamentally, such evolutionary theorising is grounded in the premises that an individual's behaviour is directed by "bounded" or "procedural" rationality (Simon, 1959, 1965) that leads to satisficing behaviour, e.d. people are prone to change their behaviour rules (routines) only when it is clear that these cannot lead to satisfactory outcomes (Fagerberg, 2003).

Such theoretical premises help build the understanding of the barriers and drivers for change and, therefore, have particular value for the management of foresight activities. In accordance with evolutionary theorizing, foresight activities can be likened to action research (e.g. Argyris et al. 1985); research orientation improves the understanding of the dynamics of the innovation system, and action fosters change towards the desirable future. Moreover, this provides a methodological framework for the coherent deployment of foresight methods developed in different scientific paradigms.

3 Methodology

The methodology of this exploratory research builds on the action research paradigm. It subsumes a variety of methodologies such as Checkland's soft systems analysis (Checkland, 1981) and Argyris' action science (Argyris et al., 1985), which are inherently cyclic, participatory, qualitative and reflective. In particular, papers (1), (5) and (6) build on case studies on the foresight processes, in which the author was one of the coordinators. The coordinators elaborated iteratively the management approach while they conducted the processes. One of the strengths of the foresight processes is the combined use of different methods, parallel to triangulation (Singleton and Straits, 1999) in the search for valid results. Consistent with the premises of action research,

the methods used in different phases of this dissertation include literature reviews, semi-structured interviews, direct observations, Internet-based group support systems, multicriteria decision analysis, trend analysis and computer assisted workshops.

Case studies are suitable for describing new phenomena, but are subject to interpretation biases and contingency factors not present or transparent in the case descriptions (Yin, 2003). Consequently, papers (2), (3) and (4) can be characterized as empirically based theory building, in which emphases are laid on the elaboration of the coherent interdisciplinary theoretical framework based on the literature review and authors' experience on foresight and environmental management. The theoretical frameworks are attested by empirical proofs documented in empirically grounded materials of the examined phenomena.

4 Results

In general, the dissertation contributes to the development of coordination-oriented policy approaches in which the main question is not optimization and equilibrium, but endogenous technological and structural changes within long-term co-evolution of environmental, social and economic processes and complex systems characterized by irreversibility and uncertainty (Lundvall, 1992; Edqvist, 1997; Jacobsson & Johnson, 2000; Unruh, 2000; Kline, 2001; Mulder & Van den Bergh, 2001; Frenken et al., 2004). While such approaches largely build on the literature of utility explanations of path dependence – namely on increasing returns to scale (e.g. Arthur, 1990; North, 1990) – they also develop interdisciplinary frameworks to include also functional (Unruh, 2000), power (Galbraith, 1967), legitimacy (e.g. Beder, 1998) and acculturation (Argyris and Schön 1978; van de Ven, 1986; Tushman & O'reilly, 1997) mechanisms of path dependence. Such frameworks can help improve the understanding of the emergence of a dominant technology, concept or product as well as the complex co-evolution of different technologies and institutions and the emergence of large pervasive techno-institutional systems (Unruh, 2000). Moreover, the perspectives on path dependence may help in the creation of new pathways for alternative technologies with similar positive feedback mechanisms which ultimately can challenge the existing dominant designs (Garud & Karnøe, 2001).

Examining innovation cycles – characterized with the mechanisms of path dependence that foreclose different phases of competing technological/institutional alternatives and emerging 'dominant designs' (e.g. Unruh, 2000; Río González, 2005) – helps improve the understanding of the multiple dimensions of barriers and drivers for continuous and discontinuous changes. Paper (4) defines continuity type changes as incremental competence enhancing modifications that preserve existing production systems and sustain the existing value networks in which technologies are rooted; and discontinuity type changes that are competence destroying, radical changes that seek the replacement of existing components - or entire systems - and the creation of new value networks[1].

The mechanisms of path dependence can be identified at different levels of innovation systems. While a techno-institutional lock-in occurs on international, national and regional scales (Lundvall, 1992; Jacobsson & Johnson, 2000; Unruh, 2000), similar processes are at work within industries and even within individual organisations themselves (Edqvist, 1997; Tushman & O'reilly, 1997). In particular, incumbent companies establish their own micro-scale patch dependencies around technological production processes and management hierarchies (Tushman & O'reilly, 1997), which create stability at the company and industry levels. Industry-wide coordination

[1] Distinguishing between the two can be complicated, however, by the fact that what is discontinuous at one level of analysis may appear continuous at a higher level of analysis.

mechanisms, including standards, supply chain integration, contractual commitments and regulatory structures, can also create meso-level stability.

Within these premises, papers (2) and (3) look at the co-evolution of large techno-institutional arrangements. Paper (4) examines the mechanisms of path dependence with regard to environmental management systems. Papers (1), (5) and (6) address path dependencies in connection with the management of foresight processes in sectoral, national and international contexts.

Paper (1) is based on experiences from participatory foresight exercises and a conducted foresight process for the Finnish food and drink industries. The authors elaborate three general objectives for foresight activities, which include (i) improved systems understanding, (ii) enhanced networking and (iii) strengthened innovation activities. It is also argued that foresight is an inherently creative activity and adoption of rigorous methodologies may entail risks in that the initial questions may turn out to be of lesser relevance as the foresight process progresses. Here, the authors identified responsiveness as a relevant design variable in the management of foresight activities. It requires receptivity vis-à-vis the interests and expectations of participating stakeholders and flexibility in planning and implementation. This, in turn, has implications for decision-making structures and methodological choices. Some of these implications are examined by describing a foresight process for the Finnish food and drink industries. The promising results suggest that responsiveness is relevant also to the management of other systemic instruments (Smits & Kuhlmann, 2004).

In paper (2), the authors look for evolutionary policy responses to techno-institutional lock-in – a persistent state that creates systemic market and policy barriers to technological alternatives (Unruh 2000, 2002). The coordination role for authorities rather than corrective optimization is addressed (Metcalfe, 1995) and three evolutionary policy objectives are elaborated, including the fostering of (i) diverse technological options, (ii) common vision for the implementation of technological alternatives and (iii) changes in social and physical networks. The authors use these objectives to analyze documented experiences from environmental voluntary agreements and foresight activities. It is argued that combining the virtues of these tools into a new policy tool, named prospective voluntary agreement helps facilitate an escape from techno-institutional lock-in. The merit of prospective voluntary agreement lies with the enhancement of collaborative policy culture and inter-sectoral and interdisciplinary stakeholder learning that creates commitment to desired action for escaping lock-in.

Paper (3) elaborates the approach developed in paper (2) and applies it in the policy context of promoting the emergence of hydrogen-based energy systems (see also, Clark & Rifkin, 2006). The paper analyses techno-institutional co-evolution of hydrogen-based energy systems and elaborates on the coordination-oriented policy objectives identified in paper (2) within the context of the emerging hydrogen economy. Paper (3) explores also the application of prospective voluntary agreements as a policy tool/process that can help facilitate a move towards a hydrogen economy through foresight and negotiation. From this perspective, paper (3) looks at the recent case of the Nordic Hydrogen Energy Foresight project for evidence. The analysis suggests that the foresight process was challenged, in particular, by the inattention of invited policy-makers that limited the possibilities to envision institutional changes, crucial especially in view of the possible application of a prospective voluntary agreement type of policy process.

In paper (4), the authors broaden the scope of Environmental Management Systems (EMS) research by describing how EMS can contribute to inertia in present production

systems and can inhibit dramatic shifts toward more sustainable technologies and systems. The approach builds upon technological lock-in theory, which focuses on market coordination and technological interdependencies (David, 1989; Arthur, 1994). Building on this framework, the authors emphasize previously under appreciated non-market social forces and institutional structures that can reinforce lock-in. It is posited that the co-evolutionary mechanisms that generate increasing returns for physical technologies may also be applied to social technologies, such as management systems. The paper describes the emergence of EMS lock-in as a path dependent evolution occurring within the context of the larger quality management paradigm. While EMS may produce improvements in environmental performance, EMS may also constrain organizational focus to the exploitation of present production systems, rather than exploring discontinuous innovations (Tushman & O'Reilly, 1997). The paper questions the exuberant private and public sector support for EMS implementation and instead recommends an ambidextrous management approach which addresses also the deployment of foresight processes and broader stakeholder collaboration.

Paper (5) builds on the experiences from a pilot project for developing a novel foresight method. The paper begins with a discussion of foresight objectives from the viewpoint of diversity which may enhance innovation activities and help escape from path dependence. Although the scanning of weak signals (Ansoff, 1975) has been widely advocated for use in such contexts, the solicitation of ideas for prospective innovations may result in more focused, action-oriented and comparable reflections of future developments. Herein, consensual foresight objectives (e.g. Barré, 2002) and diversity considerations can have complementary roles in enhancing the performance of innovation systems: for example, the implementation of S&T priorities may be best pursued through the concerted efforts of rivalling coalitions that reflect different competences and technological arrangements (Tushman & O'Reilly, 1997). Paper (5) extends the recently developed Robust Portfolio Modelling (RPM) methodology (Liesiö et al., 2006) and develops and tests a new collaborative foresight method called RPM-Screening which comprises phases for the generation, revision, evaluation and analysis of innovation ideas. The encouraging experiences from this pilot project and other recent applications suggest RPM-Screening holds promise in terms of fostering diversity considerations in a variety of contexts, thereby alleviating the envisioning of alternative pathways to escape from path dependencies.

Paper (6) is based on the experiences from the foresight process conducted in connection with a European coordination tool. Although foresight is becoming increasingly relevant at the international level (Jevel, 2003; Carlsson, 2005), little methodological attention has been given to the challenges that arise from the geographical dispersion of participants or the consideration of their national and regional idiosyncrasies (Kuhlmann & Edler, 2003; Prange, 2003). The paper addresses these challenges in connection with European coordination tools – most notably ERA-NETs and European Technology Platforms. The successful management of these tools calls for multi-stakeholder processes which, however, may put particular demands on the design and deployment of foresight methodologies. Paper (6) reports also experiences from a recent foresight process that was conducted in Finland to support the development of the Strategic Research Agenda (SRA) of the Forest-Based Sector Technology Platform. In this process the foresight method RPM Screening was elaborated and applied to the solicitation, assessment and analysis of research themes which supported the development of national priorities. The results suggest the further development of similar kinds of foresight methods in support of the management of European coordination tools.

4.1 Escaping Path Dependence

Because path dependencies persist at all levels of innovation systems, it is suggested that they may appear even in the policy and management particularly designed to challenge such dynamics, thus also in the management of foresight processes and other systemic instruments (Smits & Kuhlmann, 2004). Here precautionary and responsive actions that allow evolution within the management of policy tools, and respective policy actions, are needed. Thus, the management of foresight activities should be more concerned with facilitating technological and structural changes than imposing a particular result. In line with these premises, paper (1) elaborates three general objectives for foresight processes conducted in multi-layered innovation systems, e.d.: (i) improved systems understanding, (ii) enhanced networking and (iii) strengthened innovation activities. The perspectives on path dependence have several implications on these objectives, summarised in the subsequent sections.

4.1.1 Improved Systems Understanding

Evolutionary theorizing – elaborated especially in papers (2), (3) and (4) – provides the relevant understanding of innovation systems by laying emphases on the complex interplay of technological and institutional cycles that create the pre-conditions for the emergence and co-existence of different techno-institutional pathways. In this context, the mechanisms of path dependence facilitate the exploitation of knowledge and existing resources but create also unfavourable lock-in conditions that may inhibit discontinuous changes and the exploration and development of alternative pathways. In parallel, paper (4) identifies three foci that the mechanisms of path dependence may create within organisations: i) the focus on optimisation of present production systems, ii) the focus on routinization and conformity and iii) the extrapolation of past experiences into the future planning and investment activities. Also foresight organisation may be susceptible to similar conditions, which suggests that the exploration and visioning of alternative pathways require particular attention in foresight management. Toward this end, the diversity considerations discussed especially in papers (2), (5) and (6) support the explication of the different alternatives that may be needed to challenge conventional approaches. Such alternative visions provide basis for the development of new technological and institutional arrangements of which the emerging hydrogen energy systems discussed in paper (3) is one example (see also, Clark & Rifkin, 2006).

4.1.2 Enhanced Networking

Networking enhances the connectivity of the innovation system and can improve its performance (Lundvall, 1992; Martin & Johnston, 1999). However, paper (5) discusses how excessive emphases on the strengthening of present networks and the optimization of their efficiency (Grabher and Stark, 1997) may create path dependencies which, at the extreme, lead to techno-institutional conditions that lock-out alternative technological options (Beder, 1998; Unruh, 2000). Thus, in addition to strengthening existing networks, foresight activities should also contribute to the creative restructuring or even destruction of possible lock-in conditions by engaging different stakeholders in the proactive generation of rivalling visions on the future. Especially, discontinuous changes require a redefinition of stakeholder roles and institutional structures, as well as actual changes in the technological systems of concern. This process can be enhanced by engaging actors from outside the techno-institutional complex (Paper (2), (3) and (4), see also Unruh, 2000) that provide new alternatives and motivations. Paper 6 suggests the enhancement of such interactions, for instance, by defining pertinent modules in the foresight processes for engaging participants from different policy areas.

4.1.3 Strengthened Innovation Activities

While the different mechanisms of path dependence supports the development of continuity type of innovations and optimal exploitation of existing dominant designs,

they also create organisational inertia (paper (4)) that warrants foresight activities with particular focus on enhancing discontinuity type of innovation activities. Paper (5), in particular, develops the method for the generation of prospective innovation ideas on new alternatives and the amplification of diverse perspectives in the priority-setting. In the environmental case, discontinuous innovations generally require returning to the initial design phase to eliminate environmental flaws from the business model at the earliest stages possible (McDonough & Braungart, 2002). Such alterations may also require corporate transformation and restructuring of production systems, services, products and markets (Christensen, 1997; Tushman & O'Reilly, 1997). Here foresight activities may foster the development of rivalling coalitions that reflect different competences and technological arrangements.

Furthermore, discontinuity type changes necessitate double-loop learning that depends upon the questioning of existing rules and the development of new structures for changing environments (van de Ven, 1986). Papers (2) and (3) address the pertinent role of institutional changes and collaborative public-private arrangements if discontinuity type systemic innovations such as hydrogen based energy systems are to become a reality (see also, Clark & Lund, 2001). Here foresight activities can provide a relevant forum for creating bases for both technological and institutional changes.

4.1.4 Foresight within Coordination Policy Tools

The above three foresight objectives are by no means independent but closely intertwined. Mutual learning toward improved systems understanding contributes to the creation of the visions on alternative technological and institutional arrangements that mobilise new value networks to conduct enhanced innovation activities. Such an action-oriented approach is aligned with the notion that it may be beneficial to conduct foresight processes in close connection with other coordination-oriented policy tools. Paper (1) describes a foresight process in connection with the RTD program evaluation; papers (2) and (3) suggest the combined use of foresight processes and environmental voluntary agreements; and paper (6) suggests the deployment of foresight methods in the management of European coordination tools. While these experiences suggest that the locus of foresight process might be extended from informing decision-makers to engaging them in mutual learning and commitment into action, they also point to consequent tensions and trade-offs between (i) short-term policy goals vs. long-term visioning, (ii) receptivity to additional policy objectives vs. adherence to original objectives, and (iii) strict observation of deadlines vs. fulfilment of the principles of good governance. Such challenges were addressed especially in paper (6) by responding to the qualitative demands of scalability, modularity and dependability in the responsive design and deployment of foresight methods.

5 Discussion

As suggested in Sections 2 and 3, and attested in Section 4, foresight activities and policy making, in general, can be likened to action research; the hermeneutic cycles of research and action improve the understanding of the dynamics of the innovation system and foster change towards the desirable future. Moreover, the inclusion of perspectives on path dependence to this approach provides basis for the development of a coherent interdisciplinary framework. This responds to the policy and process level challenges of foresight management to envision and act upon the different prospects of alternative technologies and institutional arrangements. In accordance with these premises, the combined recommendations for further research and coordination-oriented policy development are summarised as follows:

- Policy-makers need to develop ambidextrous policy and management approaches in collaboration with different stakeholders. Providing incentives for the exploitation of existing capabilities and dominant designs, it is likely to

reinforce the mechanisms of path dependence and lock-in conditions by escalating the commitment to existing systems. Therefore, the policy and management approaches must also spur exploration of alternative pathways that foster discontinuous innovations and the restructuring of industries.

- Improved understanding of the dynamics of the innovation system and policy actions calls for further attention to the mechanisms of path dependence. While utility explanations of path dependence are fairly well understood, their explicit linkages to functional, power, legitimacy and acculturation mechanisms call for further interdisciplinary efforts. In particular, while market conditions and technological dependencies, as the obstacles for discontinuity type of changes, have been extensively studied, the impacts of management systems in general on discontinuous innovations have received scant attention, especially in the environmental management research and policy.
- Perspectives on path dependence have particular implications on the rationales to initiate, manage and evaluate foresight processes; escaping path dependence necessitates creative exploratory processes that recognize the costs of experimentation and the risks of failure in search for alternative future pathways. Otherwise, foresight is likely to escalate the commitment to existing systems. While this exploratory dissertation identified such implications, there is considerable future research required to better position foresight activities to support the coordination-oriented innovation policy and management.
- Escaping path dependencies suggests action-oriented coordination efforts. This calls for revisiting the foresight objectives to create a stronger linkage to decision-making as well as further experimentation of foresight processes in connection with other policy tools. In such processes policy-makers may take an active role in the facilitation of multi-stakeholder processes and engage not only as a sponsor of RTD but also in its capacity as a regulator and a standard setter. This supports the commitment into action but creates also new tensions and challenges for foresight that should be studied further.
- In order to spur the diffusion of discontinuous innovations, it is pertinent to aim at the sufficient scale of initiatives to activate the positive feedback mechanisms akin to the ones that support the path dependent predominance of existing systems. Here the internationalisation of innovation systems offers considerable opportunities to develop larger scale initiatives for discontinuous systemic changes. In the management of the European coordination tools, the identified challenges of dealing with multiple interfaces propose the further methodological developments akin to RPM Screening that enable addressing the demands of scalability, modularity and dependability. Moreover, in view of the perspectives on path dependence, the further elaboration of RPM Screening, for instance, may address the identification of prospective innovation ideas or research themes with respect to alternative future scenarios that could support the formation of new value networks facilitating the development of alternative technological and institutional arrangements.

The findings on the different dimensions of path dependence in the innovation system and respective implications to foresight and environmental management open up also a wider discussion on the role of interdisciplinary and –sectoral policy processes and their research. During the past few decades, the rapid expansion of knowledge production and distribution has created great variety of respective societal responses. For example, some scientific disciplines (in particular life sciences and environmental sciences) stress inter-disciplinary research, while others (e.g. mainstream economics and some engineering sciences) have taken more path dependent and adversary position towards other disciplines (Klein, 1990). Parallel variety of responses can be identified at the organizational level both in private and public entities. In this context,

this dissertation can be seen in broader terms as an exploration on different organizational responses to escape path dependence.

Because different organisational structures and cultures as well as different sectoral and local conditions create particular case specific path dependencies, the caution should be made in the transformation of foresight results from one context to another. In general, understanding the case-specific changing conditions (including the history) in which the policy actions are taken forward requires not only scrutiny in the management of policy processes but also the overarching development of evolutionary and collaborative policy culture that promotes mutual learning and common action across innovation systems. The findings of the dissertation are indicative of the transformation of Finnish and European innovation policy from mere financing to the facilitation and monitoring of stakeholder processes, instead of acting as a central agent of controlled agenda setting and resource allocation. In fact, this transformation may represent a fundamental shift from optimisation-oriented innovation policies for the mitigation of market failures towards coordination-oriented policies (Metcalfe, 1995) where policy-makers interact with other stakeholders in learning processes, thus creating new innovation coalitions and institutions with distributed strategic intelligence (Smits & Kuhlmann, 2004).

The further development and experimentation of foresight processes offer a relevant avenue for the implementation of coordination-oriented policy. However, the conventional positioning of foresight as a decision support process designed to inform decision-makers has set foresight processes in the hands of "experts" rather than engaging also policy-makers. While this perspective may still be largely supported by foresight practitioners as a natural path dependent continuum from the forecasting paradigm, it may hamper answering the expectations on foresight to foster also discontinuous changes. Such changes require not only the creative exploration of alternative technological and institutional arrangements but also the corresponding public-private agenda development that fosters commitment into action. Whereas this exploratory dissertation identifies and responds to these challenges by examining foresight processes in connection with other policy tools and by developing responsive and modular foresight approaches, further policy experimentation is recommended to ensure policy learning and collection of further evidence for the findings.

References

Ansoff, I. (1975). Managing Strategic Surprise by Response to Weak Signals, California Management Review 17 (2), 21–33.

Argyris, C. and Schön, D. (1978). Organizational Learning. Addison-Wesley, Reading, MA.

Argyris, C., Putnam, R. and Smith, D. (1985). Action Science: Concepts, Methods and Skills for Research and Intervention. Jossey-Bass, San Francisco, CA.

Arthur, W.B. (1989). Competing Technologies, Increasing Returns and Lock-in by Historical Events, Economic Journal 99, 116–131.

Arthur, W.B. (1990). Positive Feedbacks in the Economy, Scientific American, February, 92–99.

Arthur, B. (1994). Increasing Returns and Path Dependence in the Economy. University of Michigan Press, Ann Arbor.

Barré, R. (2002). Synthesis of Technology Foresight. In Tübke, A. Ducatel, K., Gavigan, J. and Moncada, P. Strategic Policy Intelligence: Current Trends, the State of Play and Perspectives. Institute for Prospective Technological Studies (IPTS), Technical Report EUR-20137-EN, Seville.

Beder, S. (1998). Global Spin: the Corporate Assault on Environmentalism. Chelsea Green Publishing, White River Junction, VT.

Carlsson, B. (2005). Internationalization of Innovation Systems: A Survey of the Literature, Research Policy, to appear.

Checkland, P. (1981). Systems Thinking: Systems Practice. Wiley, Chichester.

Christensen, C.M. (1997). The Innovator´s Dilemma, HBS Press, Boston, MA.

Clark, W.W. and Lund, H. (2001). Civic markets in the California Energy crisis, International Journal of Global Energy Issues 16(4), 328-344.

Clark, W.W. and Rifkin, J. (2006). A Green Hydrogen Economy, Energy Policy, to appear.

Cuhls, K. (2003). From Forecasting to Foresight Processes - New Participative Foresight Activities in Germany, Journal of Forecasting 22, (2-3), 93–111.

David, P.A. (1985). Clio and the Economics of QWERTY, The American Economic Review, 75(2), 332–337.

David, P.A. (1989). Path Dependence and Predictability in Dynamic Systems with Local Network Externalities: A Paradigm for Historical Economics, High Technology Impact Program Working Paper, Center for Economic Policy Research, Standford University.

Dosi, G., Freeman, C., Nelson, R., Silverberg, G. and Soete, L. (eds.). (1988). Technical Change and Economic Theory, Pinter, London.

Edqvist, C. (ed.). (1997). Systems Innovation: Technologies, Institutions and Organisations. Pinter Publishers, London.

European Commission. (2002). Thinking, Debating and Shaping the Future: Foresight for Europe, Final Report of the High Level Expert Group for the European Commission, April 24, 2002, Brussels.

Fagerberg, J.(2003). Schumpeter and the Revival of Evolutionary Economics: an Appraisal of the Literature, Journal of Evolutionary Economics 13, 125-159.

Frenken, K., Hekkert, M. and Godfroij, P. (2004). R&D Portfolios in Environmental Friendly Automotive Propulsion: Variety, Competition and Policy Implications. Technological Forecasting and Social Change 71(5), 485-507.

Galbraith, J. (1967). The New Industrial State. Houghton-Mifflin, Boston.

Garud, R. and Karnoe, P. (2001). Path Creation and a Process of Mindful Deviation. In Garud, R. and Karnoe, P. (eds.). Path Dependence and Creation. London, Lawrence Erlbaum Associates, Mahwah, NJ, pp. 1-40.

Irvine, J. and Martin, B.R. (1984). Foresight in Science, Picking the Winners. Dover, London.

Jacobsson, S. and Johnson, A. (2000). The Diffusion of Renewable Energy Technology: An Analytical Framework and Key Issues for Research, Energy Policy 28, 625-640.
Jewell, T.(2003). International Foresight's Contribution to Globalisation, Foresight - The Journal of Futures Studies, Strategic Thinking and Policy 5(2), 46-53.
Klein, J. (1990). Interdisciplinarity: History, Theory, and Practice. Wayne State University Press, Detroit, Michigan.
Kline, D.(2001). Positive Feedback, Lock-in, and Environmental Policy, Policy Sciences 34, 95–107.
Kuhlmann, S. and Edler, J. (2003). Scenarios of Technology and Innovation Policies in Europe: Investigating Future Governance, Technological Forecasting and Social Change 70, 619-637.
Liebowitz, S.J. and Margolis, S.E. (1995). Path Dependence, Lock-in and History. Journal of Law and Economics 33, 1-25.
Liesiö, J., Mild, P. and Salo, A. (2006). Preference Programming for Robust Portfolio Modeling and Project Selection, European Journal of Operational Research, to appear (available online: http://www.rpm.hut.fi, accessed 30.1.2006).
Lundvall, B.-Å. (ed.).(1992). National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning. Pinter, London.
Mahoney, J. (2000). Path Dependence in Historical Sociology. Theory and Society 29, 507-548.
Martin, B.R. and Johnston, R.(1999). Technology Foresight for Wiring up the National Innovation System. Experiences in Britain, Austria, and New Zealand, Technological Forecasting and Social Change 60, 37–54.
McDonough, W. and Braungart, M. (2002). Cradle to Cradle: Remaking the Way We Make Things. North Point Press, New York.
Metcalfe, J.S. (1995). Technology Systems and Technology Policy in an Evolutionary Framework, Cambridge Journal of Economics, 19(1), 25-46.
Mulder, P. and van den Bergh, J. (2001). Evolutionary Economic Theories of Sustainable Development, Growth and Change 32, 110-134.
Nelson, R.R. and Winter, S.G. (2002). Evolutionary Theorizing in Economics, Journal of Economic Perspectives 16(2), 23-46.
North, D.(1990). Institutions, Institutional Change and Economic Performance, Cambridge Univ. Press, Cambridge, UK.
Prange, H. (2003). Technology and Innovation Policies in the European System of Multi-level Governance, Techikfolgenabschätzung – Theorie und Praxis 12, 2.
Río González, P. (2005). Analysing the Factors Influencing Clean Technology Adoption: A Study of the Spanish Pulp and Paper Industry, The Journal of Business Strategy and the Environment 14, 20-37.
Salo, A. and Cuhls, K. (2003). Technology Foresight - Past and Future, Journal of Forecasting 22, 79-82.
Salmenkaita, J.-P. and Salo, A. (2004). Emergent Foresight Processes: Industrial Activities in Wireless Communications. Technological Forecasting and Social Change 71(9), 897-912.
Simon, H.A.(1959). Theories of Decision Making in Economics, American Economic Review 49, 253–283.
Simon, H.A. (1965). Administrative Behaviour, 2nd ed. Free Press, New York.
Singleton, R.A. Jr. and Straits B.C. (1999). Approaches to Social Research, 3rd ed. Oxford University Press, Oxford.
Smits, R. and Kuhlmann, S. (2004). The Rise of Systemic Instruments in Innovation Policy, International Journal of Foresight and Innovation Policy 1(1), 4-32.
Tushman, M.L. and O'Reilly, C.A. (1997). Winning Through Innovation. Harward Business School Press, Boston.
Unruh, G.C. (2000). Understanding Carbon Lock-in, Energy Policy 28, 817-830.
Unruh, G.C. (2002). Escaping Carbon Lock-in, Energy Policy 30, 317-325.

Van de Ven, A. (1986). Central Problems in the Management of Innovation, Management science 32, 590-607.
Yin, R.K. (2003). Case Study Research: Design and Methods. 3rd ed. Sage Publications, Thousand Oaks, CA.

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