Technology foresight in scalar innovation systems: a spatiotemporal process perspective

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In this paper we discuss the concept of scalar innovation systems in the Nordic countries. We use empirical examples of a transnational foresight project, and provide a literature-based formulation of a scalar innovation system model that combines temporal and spatial dimensions. Our research examples show that geographical scaling brings forth new research problems and approaches for the development of innovation systems. We claim that understandings of the effects of geographical scaling are a critical element in the innovation landscape. These spatiotemporal interconnections comprise the essence of "scales" in this text. We conclude by addressing the key dimensions that are the basis for theoretical assessment of spatially bound innovation systems.

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Introduction

For some time now, scaling has been a common denominator in the debate about the development of regions in geography. There are at least three different lines of thought in this debate. The first states that every activity takes place in a global agenda and therefore activities should be understood primarily from the global perspective. This argument can be called globalism, following Beck's (2000) treatise. The key of the argument is that the upper end of the spatial continuum is the decisive scale of human endeavours. The second line, definable as "new regionalism" (e.g. Lovering 1999), states that the regions are the primary motors of economic activity in contemporary societies. This argument puts the emphasis on the lower end of the spatial continuum. The third line states that scale is a social construction created in the realization of human activities (e.g. Swyngedouw 1997). This argument stresses that there is no clear-cut categorical division between local and global scales – the spatial scales are constructed in the juxtaposition of the everyday micro-level occurrences and, thus, scale is continuously created and activated *in situ* (Massey 2001).

The scale discussion in geography has mainly concerned the spatial dimension of scaling. This paper seeks to diversify the understanding of scaling by adding more spatiotemporal emphases to the discussion. We do so by examining the interlinkages between technology foresight (TF) and innovation systems. TF is commonly associated with analysis describing and explaining the potential future development trends and disruptions of technologies and their socio-spatial impacts. Moreover, TF refers to proactive and participatory processes that link the current decisions with strategic knowledge of the potential changes in the actor's environment (e.g. Eerola & Holst-Jörgensen 2002; Könnölä et al. 2007).

The second concept, innovation system, is commonly used to refer to the overall fabric of national research and development activities. Innovation system is in most cases based on cooperation and interconnection between public organizations, private sector research and development (R&D) efforts and universities. Innovation system approaches have gained impetus in academic and policy circles since the 1990s as a key perspective for understanding the systemic nature of modern economies. Furthermore, innovation system approaches are also utilized as policy lenses to organize, mobilize and streamline the collaboration networks of multiple stakeholders in different economic environments.

Innovation systems can be approached on a spatial basis – they can be seen e.g. as national or regional systems – or they can be approached as sectoral systems (e.g. Lundvall 1992; Cooke et al. 1997; Malerba 2002; Inkinen & Jauhiainen 2006). National and regional levels are the most widely used spatial levels to which innovation scales are associated. The concept of "scalar" has been used to describe and explain the scaling processes of various societal issues including politics, economics and local development as well as methodology (e.g. Swyngedouw 1997; Brenner 2001; Boyle 2002; Deas & Giordano 2003; Lindseth 2006; Bailey 2007). In the context of our study, innovation creation in the contemporary world is in most cases an international affair. This is due to the expansion of global markets. "National" innovation system refers to these activities within a nation state embedded in international networks. For example, international scholarly exchange is one expression of the expansion of the national innovation system to the international scale.

The Nordic countries provide a feasible platform to demonstrate selected empirical examples of the innovation processes and paths taking place in the current knowledge-based economies. Several points make the Nordic countries of global interest. First, Denmark, Finland, Norway and Sweden constantly score top-ten positions on practically all scales of measurement on innovation and R&D indexes (e.g. OECD 2007; WEF 2007). Second, the Nordic countries have public sector driven innovation systems. There are national differences among these systems (Suorsa 2007) but their goals and key methods are, to a large extent, similar and complementary to each other. Third, all of the countries have relatively high taxation levels and support a large public sector to provide a platform for the Nordic welfare system.

In this paper we discuss the concept of scalar innovation systems in the Nordic countries. To back up the discussion, we present some empirical examples of the foresight project called *Nordic ICT Foresight* (see Ahlqvist et al. 2007a, 2007b). Our examples show that geographical scaling brings forth new research problems and challenges for the development of innovation systems. Furthermore, understanding the effects of geographical scaling as a critical element in the innovation landscape can also shed light on the much debated issues of the present and future locations of R&D. In order to take up the task we shall provide a literature-based discussion on innovation systems and technology foresight. On the basis of international debate we propose a schematic model in order to display the relationships between the spatial and temporal scales.

Scalar innovation systems and technological development

Innovation system, spatial scale and technology foresight

Geographical concepts are widely used in the analyses and debates surrounding innovation creation. In these debates, national and regional categories are the most employed. The scalar process involves recognition of spatial changes taking place between individual, local, regional, national, transnational and international levels. The geographical scale has several implications for innovation policies and systems. R&D activities and development processes are often studied through a narrowly focused lens, with one selected spatial scale. European-level analysis has been conducted in e.g. the European Spatial Observation Network (ESPON 2004). The ESPON project can also be regarded as one example of combining regional-, national- and international-level knowledge of R&D under a common framework (Inkinen 2005: 1117–1118).

There are several possibilities for approaching spatial scale as a measurable setting for innovation activities (see Uotila & Ahlqvist 2007). The most common is physical distance and proximity. For example, Fischer (2001) has analysed the role of geographical proximity in the innovation processes. He points out that close proximity is a beneficial but not the only sufficient factor in the innovation creation. Cooke, on the other hand, (2001) approaches regional innovation systems as a kind of international bottom-up processes. He argues that the regional development process is inevitably interconnected with the functioning of national and international partnerships and networks of collaboration. This view has also been supported by analyses concentrating on selected industrial segments (cf. Cooke 2002). Furthermore, Koch and Stahlecker (2006: 141) provide conclusions regarding proximity and innovation creation in three cities in Germany. They argue that in the early phases of the development of KIBS (knowledge-intensive business services) firms, the proximity of suppliers and clients plays a decisive role. This is interlinked with the circulation of tacit knowledge in close geographical settings. Moreover, proximity induces the possibilities of attaining highly skilled labour.

The conclusions of Koch and Stahlecker stress the role of the private sector in the innovation system. Knowledge-intensive companies are the driving motors of a knowledge-based economy both in terms of employment and financial investments. In the same vein, the study of Leiponen (2001) reveals the fine line between organizational knowledge creation and individual knowledge creation. Thus the significance of one or two key persons in an innovative organization can become too great and a problem arises if the goals of these key persons and the organization begin to differ. Therefore, the knowledge management is also a question of human resource management.

We have conceptualized some key elements and actors in the Finnish national innovation system in the Fig. 1. The public sector is the driving motor in innovation system creation, because the public sector fundamentally aims to increase the wealth of the national economy. Since the 1990s, innovation creation and the development of a knowledge-based economy have been of great interest to the public sector. In order to breed innovations, innovation system approaches have been developed at different geographical and sectoral levels. Innovation systems include individuals, organizational networks and collaboration arrangements. Flows of finances, information and human competences mediate in these networks. Innovation production thus intertwines interests of the private, pubic and university sectors. This intertwinement has been characterized as the "triple helix" (Etzkowitz & Leydesdorff 2000) or BUG model (e.g. Anttiroiko & Kasvio 2005).

An essential part of the national innovation system is the university sector. Husso (2001) discusses the geographical attributes of the Finnish innovation system with specific reference to universities. He concludes that the goals of university research within the framework of innovation systems change over time. These changes concern goals of the supported R&D activity. According to Husso (2001: 49) the main challenge in the integration process of innovation systems is "the conflict between the external control of universities and the science system and the internal values and objectives of scientific research." Therefore, organizational changes are needed but the methods of integrating the innovation system have to struggle with organizational borders and different value spheres.

An interesting example of a chancing innovation system is the process of renewal of the highest

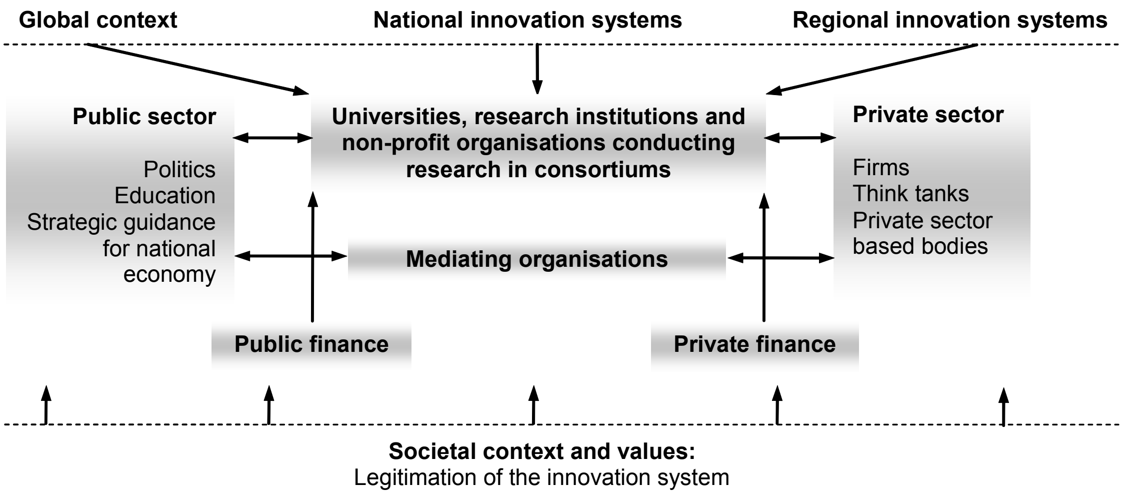

Fig. 1. Characterization of a national innovation system. Modified from Suorsa (2006).

education currently taking place in Finland. In this process, Finnish universities are required to enhance and streamline their research in order to yield results that are more applicable from the product development and business perspectives. For example, the concept of "innovation university" has been deployed in the Helsinki capital area. It refers to a plan to combine the Helsinki University of Technology, Helsinki School of Economics and School of Art and Design. This new structure is planned to be coordinated and financed in close cooperation with industry and government. "Innovation university" is an example of a locally situated organisational structure that is perceived, mainly by the public and private sector, as a potential motor of the national innovation system. Regional specifications are also occurring in other parts of Finland in the discussions dealing with the future of the national university system. The key drivers in the restructuring of the university sector are innovation pressures based on global university benchmarks. Thus the local intertwines with the regional and national according to international pressures.

In Fig. 1, regional innovation system refers to actions conducted by local-level organizations distributing the financial attributes from regionally targeted funds. In the case of Finland, the European Union's regional development funds are an example of this. The funding source comes from an international spatial scale (EU) and the financial resources are distributed in the national economy through regional and local actors. Regional support funds are also fixed to a location that limits the amount of potential beneficiaries to those who are located in that specific support area.

The scheme presented in Fig. 1 provides the starting platform for our analysis. The innovation and knowledge creation process is pivotal in knowledge transfer. In other words, the macro-level innovation system approach of Fig. 1 should be understood on specified organizational levels. One of the most widely known analyses is the theory of organizational knowledge creation by Nonaka and Takeuchi (1995). In their SECI model (*socialization, externalization, combination, internalization*) the initial letters refer to the conversion of information in different stages of knowledge processing. The concepts of "tacit" and "explicit" knowledge are used in their framework to explicate differences in different knowledge types. The SECI model provides a rather pragmatic approach to the knowledge creation process. The actual processes and emerging new practices are contextual and are created in certain organizational settings. Similarly, Conceição and Heitor (2007: 2) point out the distinctiveness of local, regional, national and international contexts of R&D policies. They argue that the innovation system policies are primarily based on a linear view of innovation; i.e., financial and material inputs to R&D yield higher innovation outputs, whereas the research results show that there are no self-evident linear causalities between the inputs and outputs. Quite the contrary, in scholar communities the innovation process is increasingly understood as a complex multidimensional process based on networked relations. Therefore there is a gap between research theory and political practice and a growing need to translate and mediate these network perspectives into the field of actual policy-making.

Our approach towards knowledge creation and innovation systems shows that knowledge transfer processes and innovation system practices are spatially interlinked. Local action can be regionally, nationally or internationally funded and the action results in innovation with possible extensions to the global scale via networks on all spatial scales. The real challenge lies in the information transfer from one scale to another in a way that avoids unnecessary overlapping. For example, the development of e-governance services seems to have significant overlapping between national- and local-level administrations.

We conclude this section by addressing the connection between innovation systems and TF. This can be regarded as a tool for the strategic management of an innovation system. Georghiou and Keenan (2006: 764) have defined five classification steps to demonstrate the essence of TF. According to them, TF aims at: 1) exploring future opportunities so as to set priorities for investment in science and innovation activities, 2) reorienting science and innovation systems, 3) demonstrating the vitality of science and innovation systems, 4) bringing new actors into the strategic debate and finally 5) building new networks and linkages across fields, sectors and markets or around problems.

These five points can be seen to include policy relevance (1 & 2), assessment (3) and networking (4 & 5). TF thus incorporates aspects of applied research with policy and networking practices. Our aim is to discuss these dimensions of TF through the lens of spatial scales. For example, points 4 and 5 on the list suggest that technological development and change is fundamentally connected to strategic planning and social networking structures. This issue has also been discussed by Kameoka et al. (2004), who bring up the question of socioeconomic levels in the foresight procedures. The view of integrating multiple activity levels in the TF process creates challenges, because foresights are usually focused on quite broad macro-level themes. Socioeconomic and human centred needs, on the other hand, are mainly micro-level issues taking place in local environments. Furthermore, this creates a need to balance long-term temporal perspectives with contemporary policy practices.

What is required, in one respect, is a more systemic understanding of the channels through which the technological development actualizes in a certain socio-spatial setting. Georghiou and Keenan (2006: 775) raise this point in their conclusions as follows: "A systematic understanding of the rationale behind a particular foresight intervention can in turn lead to an evaluation framework. However, the systems rationale also leads us to the realisation that foresight cannot be evaluated independently of its context". The contextualisation of TF is probably one of the key issues which innovation-driven local economies face in the short term. Therefore, innovation processes happen in multiscaled contexts – they are activated by local actors (individual and actor contexts) in localized spatiotemporal histories (community context) in the context of national and transnational relations.

Towards the scaling of innovation geographies

Spatial scale has several impacts on the design and methodology of the analysis of technological change. The broader the scale, the more general and quantifiable are the tools, measurements and policy recommendations. Spatial scale amounts to much more than just geographical proximity or mere physical distance. The concepts of relative and relational (see Harvey 1973) or socially lived, mentally signified and experienced (see Simonsen 1996) spatialities can be used as a starting point for opening up the scaling process.

The first thing is to recognize that technologies are pervasive and their impacts on social settings take place in a permeating manner. The source of technological development lies in the innovations. Innovation has traditionally been defined as a new solution that either manifests itself as a new end-product or service (radical innovation) or as a means to improve existing organizational functioning through the service or production process (incremental innovation). Innovation can thus be a product or service or a solution to improve efficiency. Innovations, by definition, should have a market value or an impact on economic measurements. In addition, in the field of geography, innovation has been traditionally understood as a spatial diffusion process where new inventions and technologies spread from the centres towards the peripheries (e.g. Dicken & Lloyd 1990: 239–245).

Spatial structures are always in a state of change. Changes take place within and between the actors operating on specific spatial scales (ref. Fig. 1). At least the following essential macro-scale processes causing the changes can be identified: 1) economic globalization and the emergence of new markets, 2) the changing focuses in the development of technologies, 3) changing preferences in lifestyles and values and 4) environmental change and the condition of nature. As broad meta-categories these factors also have an impact on R&D investments and profiling of scaled innovation systems. These top-level macro phenomena are factors influencing the international sphere of innovation system scaling.

Interestingly, the development of a "knowledge-based society" or "information society" is very much understood as a national issue. This perspective is based on various e-society benchmark studies that compare nations according their performance on R&D indicators. However, national-level analyses can be questioned on the basis of organizational sectors and the "essence" of international innovation creation. For example, in Finland private sector R&D equals some 70% of the whole national expenditure whereas the public sector proportion is 10% and the university sector is some 20%. The functioning of the private sector, strongly influenced by the importance of Nokia and its subcontracting network, is driven by global market logic. Therefore, the measuring of the R&D expenditure of a multinational corporation is not mainly a national issue. Product and process development takes place across the world and the product markets are also global. This obvious point demonstrates the problematic behind assessing national knowledge intensiveness on the basis of measurement traditions that have their roots in state-centric worldviews.

As a result of the considerations, we present the following scheme that depicts the meta-factors of spatial scaling in the context of TF. Our conceptualization is based on the fact that *construction* and *production* are always local issues in the sense of actual manufacturing and design. Development and production must be done physically somewhere and therefore there are micro-level issues of individuals, organizations and their local-scale combinations. In the networked development process, nonetheless, the spatial scales are overlapping. The local scale is integrated to the regional and national by networked structures. The national hosts the regional whereas the national is embedded in the international. The international can be regarded as the test-bench for innovative products. Whether or not they will break through depends on the needs and demands of the current market situation.

Fig. 2 shows that the spatial scales are intertwined with the societal actors. Organizational arrangements and development actions generated through cooperation forms the basis for spatial scaling processing. Therefore, innovation systems and R&D are a fruitful starting point for spatial scaling typology because of the international "spirit" of research. The essence of science as an international affair thus helps the process of knowledge transfer of individuals and teams. Our framework demonstrates the flux of components relevant to R&D systems. Knowledge creation and human capital are fundamentally bound to key individuals, their teams and networks. The local development of innovation transcends the spatial scales

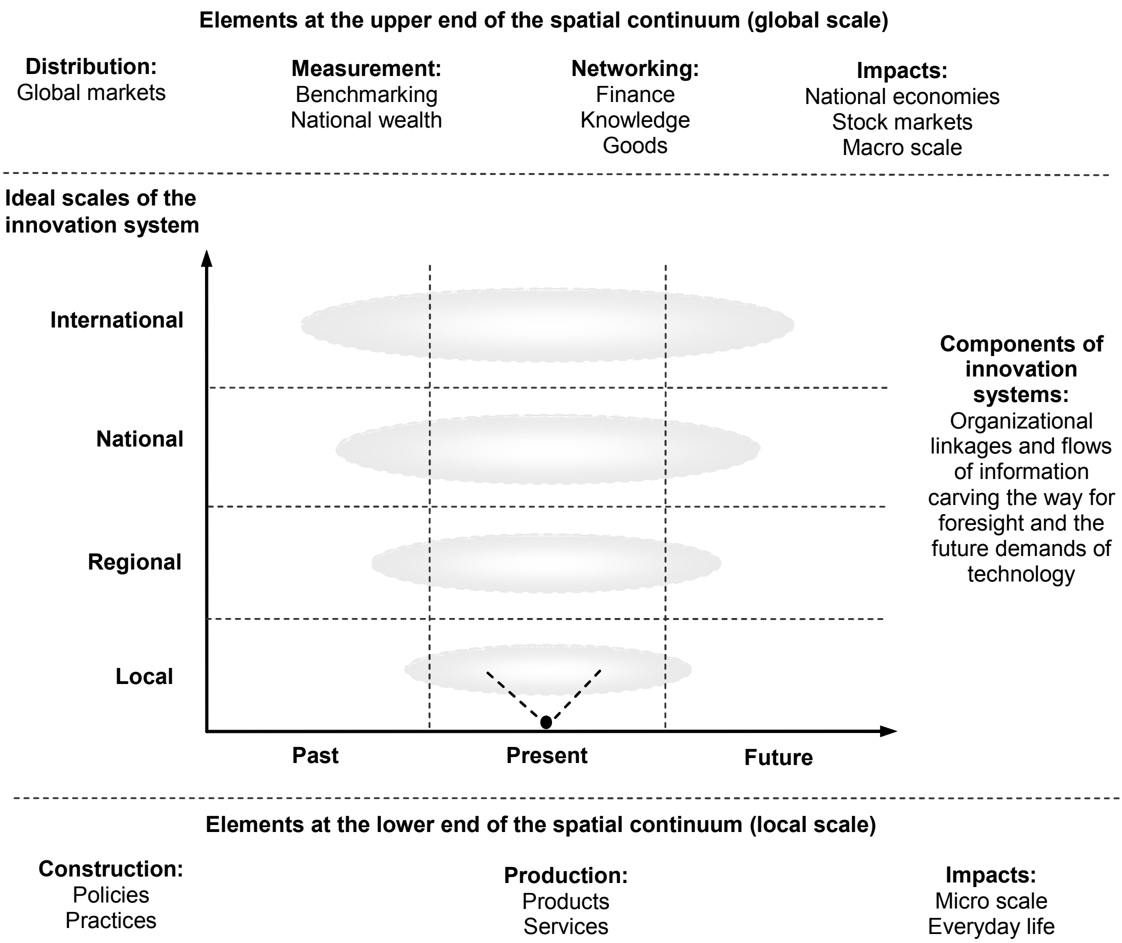

Fig. 2. Ideal model of a spatiotemporally scaled innovation system.

from this local production level to broader spatial scales. Production location is also a market scale but commonly R&D-based product development aims at global markets that are commonly the only level capable of providing a potentially extensive pool of customers.

We can exemplify spatial scaling and technological change by looking at the digitalization of television broadcasting, a process that is currently taking place in the Nordic and other industrialized countries. Firstly, the scaling process starts from the international level: different nations can be benchmarked and compared with each other in respect of "digitalized development". The international level is essential in the development of new services that have a global market potential. The second phase in the scaling process considers the national level. Here, digitalization is managed and governed by the national administrations. Thus the implementation is bound to the national development plans and national polices. National innovation system structures can also be used to support the execution of the implementation. In addition, state owned national television companies and related agencies are the major organizations behind the change.

The third spatial scale emerges because digitalization requires actions and cooperation from regional players such as local operators and service providers. These can also be national or international players. The regional level also becomes important when considering the advertising for local markets and the operability of commercial television companies. Fourthly and finally, the actual successfulness of the digitalization is dependent on local customer adoption of the technology. If there are too many households without the prerequisites to change the *status quo*, the whole project might encounter critical difficulties. This has happened in Finland where the initial goal was to end all analogical broadcasts on one date (31.8.2007). Now, the decision-makers have stated exceptions to already agreed decisions resulting to frustration of the consumers and retailers of electronics. This demonstrates the importance of aligning long-term strategic planning with present policy-making.

On the basis of Fig. 2, a triad combining space, time and process can be extrapolated. Space is explicitly present in the figure through spatial scales. The figure lists some decisive elements in the local scale (lower part of Fig. 2), such as construction, production and impacts. In the global scale (upper part of Fig. 2) the decisive elements are listed under the headings of distribution, management, networking and impacts. Time is brought into the picture through three temporal levels: past, present and future. It should be noted that Fig. 2 is an ideal model and thus in order to attain a more strategic temporal perspective one should add different future temporalities. These temporalities could include e.g. short-term span (1–5 years), medium-term span (5–10 years) and long-term span (over 10 years). The third level of the model is the actual process and its perspective, as is sketched in the present dimension of the figure (dot with lines). This process level is decisive in the actualization of spatiotemporal scales in the innovation system, since it is in the research and development processes that the approaches combining different spatial and temporal scales are constructed. The process level constructs a kind of "hermetic" worldview: it creates a view on the past spatiotemporal scales from which it is emerging; it creates an awareness of its present location and visions about its future positions in this matrix.

Scaling perspectives in the Nordic ICT Foresight project

Scaling research process in a TF project

In this section, we discuss the questions of technology foresight and spatial scales on the basis of selected results from the Nordic ICT Foresight project. We discuss and interpret some results of the project in a fashion that depicts the key levels – process, time and space – of the spatiotemporally scaled innovation system model presented in Fig. 2. It can be summarized at the start that the project's spatial perspective in the middle ground between national and EU levels created its research approaches. Furthermore, the temporal perspective that looked forwards to the Nordic ICT applications and ICT environments ten years from now, created a tension between present-day actions and future strategies.

The complete research reports of the Nordic ICT Foresight project are to be published in 2007 (see Ahlqvist et al. 2007a, 2007b). The core partners in the process were the VTT Technical Research Centre of Finland, FOI Swedish Defence Research Agency, SINTEF Norwegian Institute of Technology and DTI Danish Technological Institute. In addition to the core partners some 15 cooperation partners contributed to the Nordic ICT Foresight process by participating in the workshops and giving expert viewpoints in the different phases of the project. The data in the research process was gathered in three steps: 1) desktop survey, 2) expert workshops (multiple preparatory meetings and small organizational workshops; three larger and structured international workshops) and 3) additional expert iterations via small surveys and comment rounds (see Ahlqvist et al. 2007a).

The main aim of the project was to identify key future developments of the ICT applications in the Nordic context. It should be noted that the spatial component of the project is "between" the ideal scales of the model presented in Fig. 2. The spatial target of the results was transnational, i.e. the project was to reflect on the possibilities and challenges of the Nordic innovation system as a collective. This spatial dimension is, however, tightly linked to the up-scaled European (international) context since the somewhat explicit political idea was to enhance Nordic cooperation activities in European development. Moreover, there were also down-scaled dimensions that conditioned the transnational spatial target of the project. The key contexts of the innovation systems on the Nordic level are obviously national. Therefore, the national level was framing the foresight analyses. There were also some regional scale nuances to the study (e.g. in the context of remote sensing applications for the Barents Sea, see Ahlqvist et al. 2007a, 2007b), although the critical analytical insight travelled between the national, transnational (Nordic) and international (European) scales.

The transnational scale, between international and national, produced interesting twists in the research process. Firstly, it created some problems in defining suitable technological aims. The key problematic of the study was general: the analysis of the futures of ICT applications and related environments on the Nordic level. These issues, to be assessed coherently and systematically, needed a framework. The problem was that the framework should not direct the study excessively; at least it should not level off the potential new ideas and insights gained during the process.

The technological themes of the project were thus divided into four broad categories: experience economy, health, production economy and security. *Experience economy* widely covers the media, communication and entertainment applications of ICT. It touches upon such themes as mobility, content digitalization, new terminals, user interface development and user-generated content. *Health* emphasizes consequences of ICTs in the health sector and discusses such issues as health information systems, document distribution, storing and management, data organization, health consultation, self medication, home care and support for the elderly. *Production economy* considers the ICT applications in the production industries. In the theme of production economy such topics as Internet-based information systems, logistics, and industrial sensor systems are of importance. In the fourth theme, *security*, the focus is on security in general and on information security in particular. Security in general covers issues such as general crisis management, natural catastrophes, and prediction and prevention of external and internal infrastructural crises.

The project's view in terms of scale was also reflected on the level of research questions. Since the national or sub-national level was not the appropriate one for this study, the researchers had to synthesize national-level exercises, such as national foresight studies, and regional, or even local, case examples into a Nordic-level research challenge. Indeed, the transnational scale induced some interesting reflections on the sociocultural elements of ICT adoption. The key question to be answered was the following: what is the special value and meaning of "Nordicness" in the context of ICT applications.

In the actual research process there were five research phases. In the first phase, desktop survey, the boundaries of the technological field were defined. The second phase, SWOT analysis, identified trends in the national ICT business and research environment in four Nordic countries: Finland, Sweden, Norway and Denmark. The third research phase, the scenario and vision workshop, had two purposes: to create a set of external scenarios in Nordic ICT applications and to produce a set of socio-technical ICT application visions. The fourth phase, the roadmapping workshop, created roadmaps on socio-technical visions at the levels of science and education, technologies, businesses and industries, markets and government. In the final research phase, the action workshop, a set of actions to be taken by the key players in the Nordic countries were depicted. In addition to these research intensive phases, dissemination and evaluation activities were also included in the project.

The key results of the desktop survey illustrate that there are significant differences in scope, scale and goals for foresight activities in the analysed

Nordic countries. It can be stated in a generalized fashion that the studied Swedish material had strong descriptive socio-technical emphases, the Danish material combined descriptive technological emphases with societal-flavoured policy recommendations and the Norwegian material combined mainly descriptive technological and policy foci with some societal emphases. The Finnish material combined mainly descriptive technological foci with quite technologically oriented policy initiatives (cf. innovation policy, see Suorsa 2007 in this volume).

The steps in the Nordic ICT Foresight project suggest that the scaling has both temporal and spatial nuances in the descriptive and analytical tasks. Therefore the scalar approach of innovation production is relevant in the mode of description and explanation, i.e. in the way how issues are selected, discussed and presented. This is a detailed way of looking at "top-down" or "bottom-up" modes of thinking on the collective and spatially bound entities as suggested in the model framework of Fig. 2.

Examples of temporality and spatiality

We have discussed the scaling process on the basis of the research design of the Nordic ICT Foresight project. This is a question of research process – design, sampling and methodology. It is also a question of how reality is analysed and presented. The second step that needs to be taken is to assess the phenomena giving the content to our scalar model. In order to assess the content we take a closer look on the constructed socio-technical roadmaps. These were constructed for each of the four Nordic ICT Foresight themes (experience economy, health, production economy, security). Table 1 presents a summary of these roadmaps with three timescales.

The example presented shows that when one is to consider realising alternatives of development paths one should have *temporal* dimensions in the research design. This example clarifies the importance of time in our conceptual model (Fig. 2). The technological solutions of Table 1 should be considered as content fields of a particular issue – technology in our case. The dynamic changes in technological roadmaps show the increase of generality when moving towards longer time-periods. Spatial implications are also more difficult to assess for the longer periods: how will markets change and what spatial consequences do technological changes cause?

Table 1 shows that the short-term changes of ICT solutions are related to different user-contexts of technology (cf. Inkinen 2006) whereas in the medium term (5–10 years) there is an overall trend towards the actualization of a mobile network society (cf. Kellerman 2006). This means that technological readiness for the realization of a new level of the network society will be "somewhat" reached. Finally, in the long term (over 10 years), the mobile network society will more or less exist. This means that the everyday environment will be equipped with sensors and communication terminals which

Table 1. Example of temporal dimension of the scalar model: Nordic level summary of roadmaps and emerging technology evaluations.

Short-term: 1–5 years	Medium-term: 5–10 years	Long-term: over 10 years
• Converging ICT solutions • Formation of modular ICT • Disparate groups of ICT technologies and products: technologies are without a common framework • Separate applications are utilized in different technological platforms: e.g. mobile, non-mobile, entertainment, work, production, and housing • Increase of relationships between different ICTs • Central technological platforms are being constructed	• Towards a mobile network society • Personally tailored communication and media services: ubi services, intelligent agents, distributed data storage and information search... • Compatible, multi-channelled devices: convergence, forming ad hoc heterogeneous networks, context awareness… • New technological solutions: 3D screens, flexible screens, fuel cell batteries etc. • Embedded intelligence in materials and objects • Convergence and compatibility of ICT groups	• Existing mobile network society > ubiquitous solutions in everyday environments • Ad hoc heterogeneous networks • Spontaneously linking and communicating devices and platforms • Everyday environment is immersed in ubiquitous solutions and embedded systems • Ambient intelligence and ubiquitous computing • Sensor networks

are constantly forming *ad hoc* links. ICT devices will network spontaneously with other devices, platforms and everyday objects. This will create possibilities for different services, but also form specific information threats. The social and ethical dimensions of technologies should already be important in societal discussions in the short and especially in the long-term – networking technologies enable transparent utopian development trajectories as well as dystopian ones (e.g. Webster 2002).

Next, we illustrate the *spatial* dimension by discussing the key outcomes of the health theme. We selected the health theme as an example, because health-specific innovation processes are working in a quite complementary fashion in all Nordic countries. The Nordic countries also have clear strengths in health technology R&D including advanced basic research and R&D in biotechnology and the medical sciences. In addition, the Nordic health infrastructures are advanced and, to a large extent, alike. An important factor is the tradition of cooperation between public and private actors. The spatial perspective of the health theme was the most predominant in the policy recommendations. As a conclusion of the project, an initiative for the creation and integration of transnational Nordic test markets for ICT applications and policies in the health sector was formed. The starting point for the test market would be to create a Nordic test market concept. This concept would form the foundation for formulating a common Nordic health record on how to store, handle and distribute patient data. The second step would be to establish a common platform of information exchange for suppliers and providers of services on the local scale. The third proposed measure would be to make a platform for the applications of distance medicine that could, if necessary, be applied on the global scale.

The discussion of the Nordic health technologies demonstrates that the Nordic ICT Foresight project approached its target countries mainly from the transnational scale with national particularities and international potentials. This analysis could be intensified by providing a regional approach from each of the nation states. The project scaling can also be considered in the other direction – towards the international level as shown in Fig. 2. The project provided some considerations of the global market potential for health products, but in general the absence of the commercialization of R&D efforts was seen as a common deficit. The transnational level could be divided into a description of all four Nordic countries included in the TF study. The problematic of scaling can be elaborated by looking at national, regional, local, institutional and individual levels of the innovation process. An example of such a scanning can be done in all countries by listing all the actors that match with the content or substance themes of the analysis in question.

Conclusions

We have proposed a framework to analyse the scalar spatiotemporal perspectives of the research and development processes. We used the scales of the Nordic ICT Foresight project in three dimensions: scaling research process, scaling temporalities and scaling spatialities. The research process was scaled form the start as a transnational exercise that aims to create a future-oriented view of ICT development at the Nordic level. The temporal scaling was done in several phases of the project. We used a selected example of the roadmap work that presented the temporal change in three time periods: short-term, medium-term and long-term. The spatial scaling of the project was completed mainly through national-level comparisons between Nordic countries that together comprise the transnational spatial category "Nordic states".

The recognition of spatial scale as an elemental part of innovation production refers to the core of economic geography and distribution of production activities. The spatial distribution of the subcontracting networks of multinational corporations is one of the current issues both in academic analysis and public debates. Our conceptual approach has shown that innovation systems are collaboration networks comprised of flows of finances, organizational agreements and political decision-making. As described, the task of understanding innovation systems on the basis of scaling spatiality is not an easy one. The framework presented here incorporates societal phenomena into a geographical and temporal context.

Our study suggests that the main geographical dimensions of spatially scaling innovation systems include:

- Recognition of spatial scale as an elemental part of innovation production
- The local as the basis of innovation creation
- Spatial interlinkages between levels of administrations (International law–EU directives

and policy–national law and governance–regional governance–local governance)
- The international level as the field of competition including market potentials, collaboration networks and global finance
- National and regional scales tend to lose their importance in the current development towards global and local levels

These points crystallize the issues we think are essential in the geographical analysis of innovation system processes shown in Fig. 2. The overall picture of the development actions requires paying attention to all special scales that are constructed through historical development paths. A seminal development in the future will be the birth of cross-national collaboration networks in innovation support. These can be called joint innovation systems including two to five participating countries aiming to create collaborative innovation support systems. This idea is now visible in the initiatives to create transnational innovation zones. The rationale behind these zones states that if one country is too small to create productive internal innovation systems it is advisable to combine resources with other countries in a similar position.

Our scalar model is designed to demonstrate the theoretical complexity that is involved. Organizational arrangements and agreements comprise the essential core of the actual realisation of the functioning of the innovation systems. The Nordic ICT Foresight project provided a technology-based analysis on a transnational scale. Future research trajectories in innovation systems could combine multiple spatiotemporal scales with technological or other substance categories. This research strategy could bring some new insights to the nuanced socio-technical relations structuring and scaling of the global landscape.

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