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AWARENESS, INSTITUTIONAL ENTREPRENEURSHIP, AND CONTRADICTIONS IN EMERGING TECHNOLOGICAL FIELDS

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Abstract

Despite extensive research on the emergence of technological fields and industries, a comprehensive theoretical explanation of what enables or inhibits the emergence of these fields has yet to be developed. To this extent, previous research has been unable to offer satisfactory theoretical explanations of the emergence and socio-cognitive dynamics of novel technological fields.

This thesis thus sets out to study the emergence of awareness and institutional entrepreneurship in novel technological fields, and the contradictions that result from emergence. As a more general contribution, the thesis aims at advancing understanding about emergence and socio-cognitive dynamics in novel technological fields. Towards this end, an institutional sociological approach to study the interplay between the micro and macro-level emergent properties in novel technological fields is outlined. This approach provides a theoretical and analytical foundation to study the central socio-cognitive dynamics that pattern the emergence of technological fields. The thesis thus sets out firstly, to identify the distinct stages, dynamics, and paths in technology field emergence, specifically focusing on the socio-cognitive micro and macro-level properties. Secondly, the thesis intends to advance a socio-cognitive analysis of the central elements that influence the emergence of institutional entrepreneurship and awareness in novel technological fields, and how agency and awareness are related. Thirdly, the thesis aims to determine how the institutional properties of the prevailing and emergent technological fields enable and constrain technology field emergence. Specifically, the focus is on understanding how institutional contradictions have an impact on the strategies available to institutional entrepreneurs and their ability to advance field emergence.

To explore these avenues of research, a multiple exploratory case study on the emergence of four technological fields, functional foods, well-being technologies, electronic publishing and printing, and modular constructional steel, was carried out. The study takes a multi-level approach, focusing on field-level, organizational-level, and individual-level emergent phenomena and their relationship. National technology programs in Finland executed during 1995-2005 were chosen as the empirical contexts to study the socio-cognitive dynamics and the emergence of technological fields. Institutional contradictions were traced to their foundations in order to account for the challenges of institutional entrepreneurship and to trace the socio-cognitive base that the emergent field challenged.

The empirical analysis shows how emergence is centrally dependent on the degree of institutional contradictions that arise between institutional carriers of the predominant field and the emergent field, and how strong these contradictions are perceived to be by the relevant actors. Depending on whether institutional contradictions are weak or strong they confront actors with different socio-cognitive dynamics. The distinction between strong and weak institutional contradictions helps to understand the different options and viable strategies for institutional work by institutional entrepreneurs. The thesis provides conceptual and methodological advances for studying the emergence of technological fields. To the practical end, the thesis provides a valuable understanding of the social and cognitive dynamics of emerging technological fields; these are useful for further directing innovation policy towards distinct contextual and institutional conditions.

Keywords Technological fields, institutional entrepreneurship, awareness, institutional contradictions, socio-cognitive dynamics.

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Tiedekunta	Informaatio- ja luonnontieteiden tiedekunta
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Tiivistelmä

Teknologia- ja teollisuusalojen syntyä ja rakentumista on viime vuosikymmeninä tutkittu paljon, mutta kattava teoreettinen selitys, mitkä tekijät mahdollistavat ja estävät näitä prosesseja, on vielä kehittämättä. Näin ollen aiemmat tutkimukset eivät ole voineet tarjota tyydyttäviä teoreettisia selityksiä emergenssistä ja sosiokognitiivisista dynamiikoista uusilla teknologia-aloilla.

Tämä väitöskirja tarkastelee tietoisuuden ja institutionaalisen yrittäjyyden syntyä ja rakentumista uusilla teknologia-aloilla sekä syntyprosesseista nousevia institutionaalisia ristiriitoja. Tämän tutkimuksen yleisluontoisempana tavoitteena on pyrkiä edistämään ymmärrystä emergenssistä ja sosiokognitiivisista dynamiikoista uusilla teknologia-aloilla. Sitä varten väitöskirjassa jäsennetään institutionaalista sosiologista lähestymistapaa tutkia mikro- ja makrotason emergenssiä ja näiden tasojen välisiä vuorovaikutuksia uusilla teknologia-aloilla. Valittu lähestymistapa tarjoaa myös teoreettisen ja analyyttisen perustan tutkia keskeisiä sosiokognitiivisia dynamiikkoja, jotka suuntaavat teknologia-alojen syntyyn ja rakentumiseen. Tutkimus pyrkii ensinnäkin tunnistamaan teknologia-alojen syntyyn liittyviä vaiheita sekä näiden sisäistä dynamiikkaa ja eri vaiheiden välisiä riippuvuuksia. Näihin liittyen tutkimus kiinnittää erityistä huomiota mikro- ja makrotason sosio-kognitiivisiin ominaispiirteisiin. Toiseksi tutkimus pyrkii edistämään sosiokognitioon perustuvaa analyysiä, jossa tarkastellaan keskeisiä institutionaalisen yrittäjyyden ja tietoisuuden syntyyn vaikuttavia tekijöitä uusilla teknologia-aloilla. Erityisesti tarkastelun kohteena on institutionaalisen yrittäjyyden ja tietoisuuden väliset riippuvuudet. Kolmanneksi tutkimuksen tarkoituksena on selvittää vallitsevan ja uuden teknologia-alan institutionaalisia ominaisuuksia, niiden välisiä ristiriitoja sekä syntyprosessia edistäviä ja rajoittavia tekijöitä. Erityisesti tutkimus pyrkii ymmärtämään näiden ristiriitojen vaikutusta institutionaalisten yrittäjien käyttämiin strategioihin ja heidän kykyihinsä vaikuttaa teknologia-alojen syntyyn ja kehittymiseen.

Tutkimuksen empiirinen osio perustuu tapaustutkimukseen neljän teknologia-alan synnystä ja rakentumisesta Suomessa. Tutkimus tarkastelee terveysvaikutteisten elintarvikkeiden, terveys- ja hyvinvointiteknologian, sähköisen kustantamisen ja painamisen sekä modulaarisen teräsrakentamisen teknologia-alojen syntyä ja kehittymistä. Kansalliset, kyseisillä aloilla vuosina 1995 – 2005 toteutetut teknologia-ohjelmat tarjoavat runsaan empiirisen aineiston tarkastella emergenssiä ja sosiokognitiivisia dynamiikkoja uusilla teknologia-aloilla. Tutkimus analysoi emergenssiä kolmella tasolla: teknologia-alatasolla, organisaatio- ja yksilötasolla. Myös tasojen väliset vuorovaikutukset ja riippuvuudet ovat analyysin kohteena. Institutionaaliset ristiriidat jäljitettiin niiden alkujuurille, jotta tutkimus pystyisi paremmin ymmärtämään institutionaalisten yrittäjien haasteita ja sitä sosiaalisen kognition perustaa, jota uusi teknologia-ala haastoi.

Empiirinen analyysi osoittaa, kuinka uusien teknologia-alojen syntyminen ja rakentuminen ovat keskeisesti riippuvaisia siitä, missä määrin vallitsevan ja uuden teknologia-alan institutionaaliset ristiriidat ovat heikkoja tai vahvoja, ja miten nämä ominaisuudet koetaan keskeisten toimijoiden välillä. Sen mukaan ovatko institutionaaliset ristiriidat heikkoja vai voimakkaita, ne luovat toimijoille eri sosiaalisen kognition haasteita. Ero vahvojen ja heikkojen institutionaalisten ristiriitojen välillä auttaa ymmärtämään eri vaihtoehtoja ja mahdollisia elinkelpoisia strategioita joita institutionaaliset yrittäjät voivat punnita. Tutkimus esittää käsitteellisen ja metodologisen viitekehyksen uusien teknologia-alojen synnyn ja rakentumisen tutkimukseen. Tutkimus tuottaa arvokasta lisätietoa uusien teknologia-alojen sosiokognitiivisista dynamiikoista ja emergenssistä. Nämä havainnot ja päätelmät ovat hyödyllisiä ohjattaessa innovaatiopolitiikkaa huomioiden edellä mainittuja institutionaalisia ristiriitoja ja edellytyksiä institutionaaliselle yrittäjyydelle.

Asiasanat Teknologia-ala, institutionaalinen yrittäjyys, tietoisuus, institutionaaliset ristiriidat, sosiokognitiivinen dynamiikka

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In spite of these complex socio-cognitive dynamics, at the end of the day, the help and support one gets from so many individuals during doctoral studies, based on a voluntary but shared interest, are truly fundamental to gaining deeper insight. Thus I want to acknowledge the enormous help and support I have received from a number of individuals who, in one way or other, have contributed to the progress of this thesis manuscript. Both they and I are aware of these debts, and hence I will only mention their names. They are, in a perfectly random order: Erkko Autio, Markku Maula, W. Richard Scott, Woody Powell, Geoffrey C. Bowker, Stéphane Guérard, Loet Leydesdorff, Nelson Phillips, Kamal Munir, Frank Geels, Maria Höyssä, Janne Hukkinen, Antti Ainamo, Juha-Antti Lamberg, James Collins, Eija Ahola, Markus Koskenlinna, Lasse Kivikko, Kaj Hedvall, Anja Kahanpää, Rolf Gustafsson and Ulla-Stina Gustafsson.

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1. INTRODUCTION

Technologies penetrate and shape industries, research and science communities, innovation structures, and society in complicated ways. New technologies trigger the emergence of new industries and technological fields, and traditional industries and respective technological fields to fade, adapt, and transform. This central idea concerning the value and necessity of technological change has guided technology and innovation policy agendas in enhancing the development of new technology-intensive industries. The ongoing globalization of industries and markets has increased the pressure for governments and economic areas to succeed in the development of new technological fields, and the requirements for efficacy in supporting adaptation and transformation of existing industries (e.g. Hung & Chu, 2006; Spencer, Murtha, & Lenway, 2005).

Several perspectives have subsequently developed for analyzing and explaining the dynamics in transitions of technological fields and the emergence of novel fields. These streams of literature include: (1) research that focuses on the functioning and dynamics of national and sector systems of innovations (Lundvall, Johnson, Andersen, & Dalum, 2002); (2) research that attends to legitimacy in the emergence of novel technological fields, by studying discourse in legitimizing novel technological fields (Phillips, Lawrence, & Hardy, 2004), and how legitimacy of actors and technologies are formed (e.g. Barley, 1986; Hargadon & Douglas, 2001; Rao, 1994; Suchman, 1995): (3) research on the role of agency and interest, specifically how institutional entrepreneurs (e.g. Garud & Karnoe, 2003), and social movements (Lounsbury, Ventresca, & Hirsch, 2003), direct and advance structuring and the emergence of technological fields, and on the role of fringe players in enabling institutional change (Leblebici, Salancik, Copay, & King, 1991): and (4) research on the social construction of technologies (Pinch & Bijker, 1987), and the closely associated actor network theory (Callon, 1986; Latour, 1991), which addresses the role of agency, interpretation, and struggles (Klein & Kleinman, 2002) in shaping, making sense and negotiating the formation of new technologies.

To this extent, research on technological fields has focused on explaining how social mechanisms facilitate and constrain institutional change of predominant fields, and what forms of actions facilitate the emergence of novel fields. Together, these literatures thus shed light on how innovation is embedded in social structures, how technologies and institutions co-evolve, and what organizational and institutional properties constrain or facilitate actors to take up action around novel technologies and engage in collaborative exploration and exploitation of technological knowledge. To conclude, these literatures provide central elements for a theory on the emergence of technological fields, particularly in those situations when existing innovation and production structures and current actions are more profoundly challenged.

Action in emerging technological fields has predominantly been addressed by studying firm behavior and market rationality (Santos & Eisenhardt, 2009). However, the basis for action and rationality of action are different for various actors in innovation. Universities, research institutes, government agencies and industry organizations, located in distinct organizational fields, develop distinct logics and governance forms and thus develop different responses to novel technological opportunities. Emergent technological fields are thus portrayed as a potentially contradictory *inter-institutional system* (Friedland & Alford, 1991). To this extent, interpretive processes and learning about novel technologies develop asynchronically among actors in prevailing structures.

The streams of literature have therefore not been able to inform each other in a productive manner to develop a coherent theory base for action in emerging technological fields, which simultaneously considers social and cognitive underpinnings. Although the neo-institutional sociology perspective has advanced research on institutional change in organizational and inter-organizational fields, specifically by focusing on institutional entrepreneurship and social movements (Maguire, Hardy, & Lawrence, 2004; Rao, Morrill, & Zald, 2000), it has paid much less attention to the distinctive characteristics of inter-organizational fields that share a common technological base. Only a few studies have specifically examined institutional change in technological fields (Hargadon et al., 2001; Leblebici et al., 1991), and institutional entrepreneurship (Garud, Jain, & Kumaraswamy, 2002; Garud et al., 2003; Granqvist, 2008) and social-movements (Lounsbury et al., 2003) in technology field emergence. This said, these few studies provide important clues for forwarding a socio-cognitive approach to studying technology field emergence.

Recently Geels (2004; 2007) has made advances in this direction, by integrating sociological and institutional perspectives into the innovation systems literature, and articulating a socio-technical framing for analyzing *"long-term dynamics, shifts from one socio-technical system to another and the co-evolution of technology and society"* (Geels, 2004:897). In this respect, Geels has positioned the socio-technical systems as the unit of analysis, embracing elements that are involved in the production, diffusion and use of technology. Socio-technical systems theorization then focuses on the interplay and coordination between different rather autonomous actors, so called multi-actor networks, in a socio-technical regime: *"the 'deepstructure' or grammar of ST-systems, … carried by the social groups"* (Geels, 2004:905). To conclude, this research has made conceptual advances for analyzing the emergence of technological fields that considers differing rationales of actors in socio-technical systems, and shows central processes in the co-evolution of technology and society.

Neo-institutional sociology has predominantly focused on explaining emergence, attraction, and diffusion with respect to mimetic, coercive and normative behavior. Previous research on institutional change and the emergence of meaning has focused mainly on field-level social and discursive mechanisms that influence dynamics of ideational and symbolic meanings (Meyer, 2008). This literature has given less attention to the socio-cognitive properties and dynamics of both knowledge structures and socio-technical regimes. To this extent, research on institutional change has not considered the distinct properties of the embeddedness of actors in prevailing technological fields, and related institutional properties. With the development of new technologies the social realities and awareness of engaged actors develop around emerging technological fields. Previous research has not explicitly considered how the locus of knowledge and institutional properties of technology itself influences how novel technologies enter existing field-level socio-cognitive structures. Although the role and actions of institutional entrepreneurs has been studied, there is little understanding of what enables them to take action, and why others do not. In this respect, previous research has not been able to link micro-level properties of knowledgeable individuals to macro-level field emergent properties and dynamics. This suggests that the previous literature has yet to explain properly the emergence of institutional entrepreneurship in novel technological fields from the actor's perspective, and how this micro-level emergent property influences subsequent field-level emergent properties in the development and shaping of novel technological fields.

To conclude, although conceptual advances on the processes and rationales for interactions in inter-organizational fields and socio-technical systems have been made, this literature has yet to consider how awareness emerges within existing knowledge structures and institutions. This suggests that the literature has not satisfactorily explained how perceptions and interpretations concerning opportunities influence the emergence of agency, and how awareness impacts subsequent actions and the unfolding of technology field emergence. A focus on socio-cognitive properties and awareness in technological fields, calls for giving attention to the properties and structure of knowledge, and its institutional properties with regard to a technological field. By simultaneously addressing socio-technical systems and the institutional properties of technology, one is able to consider the social-cognitive embeddedness of actors in prevailing technological fields, and consequential basis and rationale for action. This perspective gives attention to the path and development of knowledge and knowing structures, and how these enable actors to become aware of the opportunities of novel technologies at different stages and times during the development of novel technological fields.

The central question here is then: what are the socio-cognitive dynamics that shape the emergence of technological fields? This allows us to explore the further question: through what specific stages of emergence do novel technological fields develop? Towards this end, an institutional sociological approach to study the interplay between the micro and macro levels of emergent properties in novel technological fields is outlined. This approach provides a theoretical and analytical foundation to study the social and cognitive dynamics that pattern the emergence of technological fields, specifically focusing on awareness and arising institutional contradictions and cultural persistence (Zucker, 1977).

1.1. Research questions

This thesis outline a theory of action in emerging technological fields. The focus here is on understanding how and why agency and interest take on distinct properties around novel technological fields, and how these properties impact the subsequent development of innovation structures within technological fields.

The first research question considers the socio-cognitive properties of technology field emergence. Emergence is an elusive concept, which aims to capture the interaction within and between micro and macro levels in organizational and inter-organizational structures. *"A phenomenon is emergent when it originates in the cognition, affect, behaviors, or other characteristics of individuals, is amplified by their interactions, and manifests as higher-level, collective phenomenon*" (Kozlowski & Klein, 2000:55). Technological fields progress through different stages of emergence, what Geels (2004) has termed technological transitions, that include cascading dynamics and reconfiguration processes from predominant structures in to novel structures. Expectations, network dynamics, and agenda setting are essential elements for explaining technology field emergence (van Merkerk & Robinson, 2006). The research question thus sets out to explore:

> ***RQ1. What specific stages of emergence can be distinguished in the development of novel technological fields?***

The aim here is to identify distinct stages, dynamics, and paths in technology field emergence, specifically focusing on socio-cognitive micro and macro-level properties. The focus in the empirical study is then to identify commonalities and distinct processes in the emergence of novel technological fields, attending to the embeddedness of socio-technical systems and innovation structures. Specifically, the focus is to provide an in-depth process-based explanation of how awareness develops among actors in novel technological fields, and how institutional contradictions arise. The social network of actors engaged in innovation functions as a central carrier of technology field emergence. It compromises a relational and symbolic system based on technology and knowledge-related socio-cognitive structures. By focusing on awareness in emerging technological communities and innovation networks, the thesis sets out to explore knowledge-related social and cognitive dynamics and the distinct stages of the emergence of novel technological fields.

To explore this research question, a literature review is carried out which presents current theories on the emergence of technological fields, and how predominant fields become challenged. This review is then used to inform the development of a conceptual framework for attending to technological fields as inter-institutional structures and for studying technology field emergence from an institutional sociological perspective. A multiple case analysis on four emerging technological fields, including within and between case analyses, is then conducted. Building on insights and observations from the four cases and the extant literature on awareness, institutional entrepreneurship and institutional contradictions, propositions regarding the macro-level emergent properties in the development of novel technological fields are developed. Specifically, the chapter aims at building explanations and theory for the macro-level emergent properties and the causal links found when comparing the cases and previous research and theorization on the focal phenomena.

The second research question addresses the micro-level socio-cognitive elements that influence the emergence of institutional entrepreneurship and awareness in novel technological fields, and how agency and awareness are related. The ability to interpret, make sense, and comprehend how a technology domain is emerging and how to respond to the opportunities is conceptualized here as awareness. Awareness is a critical factor for productive learning (Bandura, 1986). Awareness facilitates the connection of actions to outcome. With regard to awareness, the thesis considers the cultural-cognitive pillar of institutions (Scott, 2008) and take a socio-cognitive perspective for interpreting agency, interest, and action in emerging technological fields. Although partly institutional, awareness about novel technological opportunities also includes substantial elements of 'consciousness' and individual and collective rationalization about opportunities and possibilities of novel technological fields. This co-evolutionary process or ‘churning’ among knowledge-value collectives[1] (Bozeman & Rogers, 2001) and related properties and characteristics of agency and interest provides pace, character, and direction for the subsequent evolution of technological fields. The second research question thus sets out to examine:

> ***RQ2. How does institutional entrepreneurship and awareness in novel technological fields develop?***

This research question investigates what connects and engages individuals and organizations to advance the development of novel technological fields. Specifically, the focus here is on understanding the underlying structural properties, together with individual traits and embeddedness-related characteristics that enable agency. Embeddedness-related characteristics are here referred to as the legitimacy of actors and their behavior in institutional fields. This provides us with a valuable understanding of why some actors engage and others do not, and explaining what impacts their level of engagement. A key issue is to understand how awareness influences the propensity for institutional entrepreneurship in novel technological fields. These initial conditions of agency offer an explanatory foundation for investigating how the emergence of agency and interest influences subsequent socio-cognitive dynamics, at both a micro and macro level, and the subsequent unfolding of novel technological fields. In this respect, agency and interest is studied as a construction through the presence of actors engaged in interpreting and enacting novel technological opportunities.

Although this research question focuses specifically on technological fields, the more general theoretical contribution is to distinguish the formation and emergence of agency and interest in technological fields from other types of organizational and inter-organizational fields. From this perspective, the research question aims to provide additional evidence of how structure and agency are related, and what kind of structural conditions and mechanisms trigger action and interest to facilitate shifts towards novel technological fields. To analyze this second research question a literature review of institutional entrepreneurship is conducted, focusing first on the more general accounts on institutional change and then specifically on institutional entrepreneurship with regards to technological fields. The case analysis then traces the emergence of institutional entrepreneurship and awareness around the novel technological fields. Thereafter based on the case analyses, and the literature review, propositions about the

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[1] A *“networks of knowledge creators and users”* is depicted as a knowledge value collective (Bozeman & Rogers, 2001: 774)

factors that contribute to individual-level awareness, and how awareness is related to institutional entrepreneurship, are outlined.

The third research question addresses the enabling and constraining factors in the emergence of technological fields. A predominant socio-technical regime, embeddedness of actors, and interdependencies within socio-technical system, results in tension, miss-alignment, and instabilities between the prevailing and emergent socio-technical regimes (Geels, 2004). System-level inertia (Gustafsson & Autio, 2007), the degree of institutionalization (Zucker, 1977) and properties of the disruption, all importantly determine tensions and institutional contradictions between multiple institutions (Clemens & Cooke, 1999; Seo & Creed, 2002). Enabling technology field emergence requires socio-political maneuvering (Garud et al., 2002) and the cognitive and socio-political legitimacy of actors (Aldrich & Fiol, 1994). The capacity of action for advancing radical institutional change stems from the available skills and resources that an actor possesses, leadership, and experience (Greenwood & Hinings, 1996). Together, institutional contradictions, agency traits, and the position of actors then influence their ability to influence institutional change and the subsequent available action strategies and policies (Clemens et al., 1999; Greenwood et al., 1996). The third research question therefore explores:

> ***RQ3. How do awareness and institutional contradictions influence the effectiveness of institutional entrepreneurship in novel technological fields?***

Where the second question considers how institutional entrepreneurship and awareness develops, the focus of the third question is on determining factors that affect the ability and efficacy of institutional entrepreneurship in relation to the distribution of awareness in innovation networks, and the properties of the emergent technological field; specifically the institutional contradictions that arise. By institutional contradictions, the thesis addresses legitimacy that undermines functional inefficiency, adaptation that undermines adaptability, intra-institutional conformity that creates inter-institutional incompatibilities, and isomorphism that conflicts with divergent interests (Seo et al., 2002:226). Institutional contradictions are analyzed in the empirical study through two perspectives: (1) contradictions in logics, interests, and practices in the exploration and exploitation of novel technological opportunities, specifically the emerging and shifting roles of actors in innovation that arise in response to novel technological and knowledge-related structures and properties; (2) contradictions in technology value and use between the predominant technology and/or the unexplored (not previously known, practiced, or imagined) value and use that new technological fields trigger and offer. Thus, the focus is on how awareness and institutional contradictions and their properties in a technological field influence the ability and available strategies of institutional entrepreneurs.

To analyze this research question a literature review on institutional contradictions, and more specifically institutional contradictions in the context of technological fields, is carried out. Towards this end, a synthesis is developed to conceptualize the institutional properties of technology. Thereafter, a conceptual framework for studying the enabling and constraining factors and effectiveness of institutional entrepreneurship, with respect to institutional contradictions and awareness in emerging technological fields, is outlined. To this extent, the third research question addresses entrainment in emergence; referring to the *"rhythm, pacing, and synchronicity of processes that link different levels"* (Kozlowski et al., 2000:24). A qualitative empirical analysis, based on the interview and archival data on the strategies of institutional entrepreneurs and prevailing institutional contradictions is carried out. Thereafter based on the case analyses, and the literature review, propositions on how the institutional properties of prevailing and emergent technological fields enable and constrain technology field emergence, are outlined. Specifically, here the focus is on understanding how institutional contradictions impact the ability and available strategies of institutional entrepreneurs to advance field emergence.

1.2. Research focus

To untangle the research questions the thesis centers on investigating emergence of technological communities around novel fields, the properties of agency and interest - specifically institutional entrepreneurship and awareness - and the social shaping of emergent technological fields. Following Kozlowski & Klein (2000), regarding studying multilevel phenomena and emergence, the defining units of analysis for this study are: the global unit of analysis is the technology field; the shared unit of analysis is awareness and institutional contradictions; the configurational units are the organization and the individual. A multi-level approach is chosen as it allows *"simultaneous consideration of the impact of human agency and institutional constraints on field evolution"* (Purdy & Gray, 2009:356).

This thesis does not focus on the overall properties of processes in the emergence of technological fields, rather, and more specifically, the focus is on socio-cognitive dynamics and the interaction between micro and macro-level emergent properties. Therefore, the general literature on technology field emergence is only covered to the extent that it relates to socio-cognitive dynamics and the institutional properties of technologies. Theoretically, the thesis is rooted in neo-institutional sociology although centrally drawing on the social construction of technology approach (Pinch et al., 1987) and the closely related actor network theory (Callon, 1986). From neo-institutional sociology, field-level research and theories on institutional change and institutional entrepreneurship are specifically covered. Central insights from neo-evolutionary economics (Etzkowitz & Leydesdorff, 2000; Malerba & Orsenigo, 1996; Nelson & Winter, 1982) and research on socio-technical systems and regimes (Geels, 2002, 2004; van Lente & Rip, 1998) are integrated.

The thesis investigates emergence in technological fields by examining institutional entrepreneurship and the formation and dynamics of technological communities and awareness. Four technological fields - functional foods, well-being technologies, electronic publishing and printing, and modular constructional steel - were chosen for the empirical study. Case selection was theoretically driven, aiming for polar types in terms of agency, governance and the properties of field-level logics (e.g. Scott, Reuf, Mendel, & Caronna, 2000; Thornton & Occasio, 1999a). The four cases were chosen as having noteworthy differences in respect to: (1) the degree of market versus non-market properties in the industry sector at focus; (2) the size of the technological field and related diversity of community; (3) the basis of institutional entrepreneurship; (4) the stage of emergence of institutional carriers of the field; and (5) the origin of institutional contradictions in technology-specific and field level innovation logics. Taken together, this provides a comparative study of the emergence of technological fields.

National technology programs in Finland executed during 1995-2004 were taken as the central focus. National technology programs represent a technology and innovation policy intervention, the intent of which is to facilitate institutional change in industrial systems, for example, by taking up emerging technological opportunities. In Finland, national technology programs are funded and organized under Tekes, the National Technology Agency of Finland. The empirical study considers the historical roots of institutional contradictions and the initial stages in the emergence of the technological fields. These historical narratives provide the socio-cognitive context in which to analyze and interpret institutional contradictions and institutional entrepreneurship during initiation, take-up, and the materialization of national technology programs in each respective technological field. Both institutional entrepreneurship and technological communities are considered resources and engines of change, although, in their behavior and perceptions they equally reflect the socio-cognitive dynamics of emergence in novel technological fields.

1.3. Research methods

The empirical study sets out to explore emergence of technological fields by attending to awareness, institutional entrepreneurship, and institutional contradictions. An exploratory multiple case study design was considered paramount for analyzing these properties of emergence and socio-cognitive dynamics around novel technological fields. A multiple case study design is most suitable when the *"boundaries between phenomena and context are not clearly evident"*(Yin, 2003:13). The case analysis draws on: (1) semi-structured interviews; (2) archival data, including electronic, printed, and written material, and (3) secondary data, including previous studies and reports on the studied technological fields.

The case analysis is framed to explore agency, interest, and action in the structuring of innovation activities from the perspective of 'multiple realities' (Schutz, 1982). The study adopts a social constructionist perspective to the understanding social life; focusing on how reality is constructed by active and creative actors through their interaction with others. This method can also be categorized as a '*process' study of organizing* where temporal predispositions and social constructions are considered (Van de Ven & Poole, 2005). The case study is then succeeded by two chapters, which based on the case analysis and extant literature on the observed phenomena's, develops propositions on macro- and micro-level emergent properties around novel technological fields. In this respect, the thesis follows the method of inductive theorizing and constant comparison, and the approach and outlined stages of theory building from cases by Eisenhardt (1989).

1.4. Core concepts

In the next section, the central concepts and constructs that are used in this thesis are presented in order to clarify their meaning and use.

1.4.1. Technology

Technology and its properties are a central element of this thesis. But there is great ambiguity around what constitutes technology. For example, the word is often used as a synonym for techniques. Scholars in the field have not been able to settle on a single definition of what is included and what is not when defining, and using the word technology. These ambiguities are very much tied to the phenomenon and the properties of technology itself. It is therefore important to present how technology is conceptualized and what dimensions of technology are addressed in this thesis.

The etymology of the word derives from the ancient Greek words 'techne' and 'logos'. Techne means art, craft, craftsmanship, or skills. Logos today refers to discipline or 'the study of', although the original definitions include the meaning of count, tell, or speak. In Merriam Webster's online dictionary, technology is defined as *"the practical application of knowledge especially in a particular area".* Technology encompasses aspects that are related to artifacts and their functions, the technical activity, the technical knowledge, and the processes of concretization (Lawson, 2008:60). Though knowledge is central in order to mould, develop, and control these properties, part of this knowledge is also more experiential and tacit (Polanyi, 1967), and is therefore not based on full understanding[2] of the phenomena. Artifacts have functions to accomplish, technical task and functions *"to extend human capabilities"* (Lawson, 2008:59). Artifacts range in terms of agentic versus non-agentic functions (Searle, 1995). This suggests that technologies include elements of power for directing and organizing activities in industry and society. These capabilities of technologies *"are realized in social and technical networks"* (Lawson, 2008:60). With emerging technologies, the intrinsic, physical, and material properties and functions of artifacts are explored. The emergence of novel technologies encompasses an *"analytical (indeed normative) category for understanding the production of meaning…the intelligent production of new tools, including conceptual and ideational ones, for dealing with problematic situations"* (Hickman, 2001:183). To this extent, new technologies are interpreted and become embedded in usages and application through a process of social construction (Berger & Luckmann, 1967).

Technologies are generative by nature (Stiegler, 1998). They enable and transform industries, societies, and most profoundly, *"what it is to be human"* (Lawson, 2008:59). As new technologies form through the dialogue and in the contexts of present technologies (technologies in application), they form the horizon of human existence (Stiegler, 1998). Technologies thus, entail the capabilities necessary to accomplish a task, but also provide the means to shape and envision future function, application and use of knowledge. This ongoing transformation of industry and society, through the perspective of technology, shapes interest, agency and action to further extend and take stock of current knowledge. In this regard, novel technology holds emergent properties that bring together actors and ideas relating to how to make use of new knowledge.

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[2] Rosenberg (1982:143) defines technology as *"a knowledge of techniques, methods, and design that work…with certain consequences, even when one cannot explain exactly why"*

These reflections of the properties of technology provide the basis for defining technology with regard to this thesis. In this thesis, technology refers to *the property and appearance of physical world, utilized, crafted, or extended, for purposeful or generative human application*. Technological knowledge then refers to knowledge and know-how emanating from these properties and appearances of physical world, which enable problem-solving, reflections, envisioning, and crafting of artifacts, tools, and functions, for extending purposeful human application. Novel technology refers to distinctively new human applications, utilization, and crafting, which emanates from previous manifestations of technology and the properties and appearances of physical laws within a technological community, which have not yet diffused widely outside the community. Novel technologies are, in this regard, new to industries and society with respect to purpose and value-creation.

1.4.2. Technological field

This thesis builds on the neo-institutional analysis of organizations for studying and addressing organizational and inter-organizational field-level effects. A central idea within this literature is that organizations are guided and influenced by shared institutional logic and related governance structures that result in anticipated behavior and action, and similar form and functions of organizations (Wooten & Hoffman, 2008). Although researchers have studied organizational fields at different levels of populations, from global society (Jepperson & Meyer, 1991) to industry sectors within specific economic regions (Leblebici et al., 1991; Scott et al., 2000) that share a common meaning system, little systematic analysis and theorization of organizations influenced by a shared technological frame has developed. By taking a technological field perspective, technology in itself is assumed to hold institutional properties that form the nexus for organizing production, use, and application of technology. In summary, technological fields are here assumed to be a specific form of organizational fields with distinct properties and dynamics arising from the underlying properties of technology and knowledge.

Garud et al. (2002:197) articulate the notion of a technological fields as a *"pattern of relationships among objects and humans related to product market domain"*. This notion is similar to what Orlikowski terms sociomaterial practices (Orlikowski, 2007). By addressing objects and humans, the organizational field is depicted as guided through the materialization of technology and knowledge in practices in addition to field logics and governance structures. Hence technological fields incorporate a collective meaning system, noted as a field frame (Lounsbury et al., 2003) or technological frame, for a larger group of actors (Bijker, 1987). Though a shared meaning system around a technological domain, actors that participate in knowledge-exploration and exploitation hold distinct logics and governance structures in relation to the field. In this way technological fields can be considered to be inter-institutional systems (Friedland et al., 1991). The concept inter-institutional system addresses *"institutions as both supra-organizational patterns of activity through which human conduct their material life in time and space, and symbolic systems through which they categorize that activity and infuse it with meaning"* (Friedland et al., 1991:232). Technological fields incorporate several distinct organizational fields, such as university, research institute, industry and government, and respectively, patterned and institutionalized agency, and interest in respect of who should be concerned and act in education, research, innovation, and commercialization around a technology. A similar conceptualization of different institutional logics of actors that engage in, and share, a common technological base is elaborated by Geels (2004). He conceptualizes this binding mechanism as a socio-technical regime that entails *"the 'deepstructure' or grammar of ST-systems ... carried by the social groups."* (Geels, 2004:905). Although socio-technical regimes embrace the idea of paradigms and technological trajectories (Dosi, 1982), the notion of technological fields draws on the institutional framework for analyzing and explaining change and stability of social structures.

At the inter-institutional level, technological fields include structures of regulative, normative and cultural cognitive systems (Scott, 2008) that shape peoples' understanding of their relationship with the past, future and present (Emirbayer & Mische, 1998). This suggests that technologies are generated through multiple institutional logics, and varying agency and interest by distinct actors connected through a shared technological field frame. In an emergent technological field actors engage in sense-making activities and identity construction around novel technologies as field frames are less apparent at this stage. These activities influence the emergence of a technological field, as they direct thought patterns, anticipation, and provide awareness and identification for actors. This conceptualization provides a dynamic property to the previous notions of organizational fields (by addressing emergence of awareness, emergence of dominant design, the influence of spillovers and externalities, dynamics of technological trajectories, and accumulation of learning), and the idea of inter-institutional systems, although still maintaining the central idea about isomorphic mechanisms that are prevalent at the macro level. The articulated dynamic property is driven by advancements in technologies and the accumulation of scientific knowledge and innovations. In this respect, emergent technological fields are pictured as potentially contradictory inter-institutional systems. This notion gives attention to the need for social theories on 'emergence', to consider three levels of analysis: individuals' competing and negotiating, organizations in conflict and coordination, and institutions in contradictions and interdependency (Friedland et al., 1991). As *"patterns of* *individual and organizational behavior vary institutionally"* (Friedland et al., 1991:243), emerging technological fields should provide a rich context for studying socio-cognitive dynamics of emerging technological fields.

1.4.3. Emergence

This thesis focuses on the emergence of technological fields. Emergence is an elusive concept, which aims to capture interaction within and between the micro and macro level in organizations and inter-organizational structures. Emergence has been defined by Goldstein (1999:49) as *"the arising of novel and coherent structures, patterns and properties during the process of self-organization in complex systems"*. The concept of emergence addresses higher-level regularities that *"are often the result of quite simple rules and local interactions at the lower level*" (Sawyer, 2001:555). Emergence thus refers to macro-level properties that form through an interactional effect between micro and macro-level social properties. Resilience, robustness, and coherence are more general properties of emergence related to organizations (Lissack & Letiche, 2002). Emergence includes amplifications, positive feedback, and tipping points, shifts of boundaries, and shifts from one order (property of emergence) to another. Emergence draws on complexity theory and includes assumptions and attendance to the characteristics of nonlinearity, self-organization, beyond equilibrium, and new attractor regimes (Goldstein, 1999). These characteristics may be properties of emergence, but may also by the underlying micro-level properties that in combination with other emergent properties generate macro-level emergence. How the emergent property can be explained through the micro-level phenomena is still contested between methodological individualists (reductionists) and non reductionists. This said, there are several problems in predicting and convincingly claiming emergent effects. Sawyer (2001:553-554) illustratively concludes that *"an emergent effect is not additive, not predictable from knowledge of its components, and not decomposable into those components"*. Emergence therefore includes the property of novelty that comes into being that was not predicted. Inventive activity is by nature emergent. The emergence of novelty in thought and action around technology is characterized by accumulated experience, a multitude of small acts of insight, 'cumulative synthesis', inconsistencies, and tensions in social systems (Usher, 1988). The emergence of technological innovations follows from multiple interrelated sequences of interactions and structural developments between different actors in innovation (Van de Ven et al, 1995:167).

This thesis considers emergence as a phenomenon that *"originates in the cognition, affect, behaviors, or other characteristics of individuals, is amplified by their interactions, and* *manifests as higher-level, collective phenomenon"* (Kozlowski et al., 2000:55). In this regard, the thesis takes a layered/stratified ontological perspective where *"reality is irreducibly layered, with physical, molecular, organic, mental, human individual and social levels"* (Hodgson, 2007:103). Emergence in this thesis refers to social-cognitive properties, at micro and macro-level that regulate, enable, and direct developments of novel technological fields.

1.4.4. Awareness

Research on managerial and organizational cognition theorizes how attention and interpretation are formed through knowledge structures that individuals and organizations draw upon. Knowledge structures are, in turn, conceptualized as mental templates that *"consist of organized knowledge about an information domain"* (Walsh, 1995:281). Combined with experience, knowledge structures provide meaning and direct action (Walsh, 1995). Although knowledge structures enable, they also constrain the directing of attention toward distinct aspects in information environments and thereby can leave other aspects unnoticed or misinterpreted.

With regard to awareness, this thesis addresses the interpretive, reflective, and attention-allocating effects the context and knowledge structure has on actors in a social context. With respect to neural processes, awareness refers to a developed higher order of control that includes expectations, goals, high-level emotional processing, and declarative memories (Toates, 2006). Attending to awareness allows one to consider the dual processing of the brain (specifically related to the frontal lobe) including the reflective and reflexive functions (Evans, 2008). The assumption here is that these two distinct brain functions interact and produce awareness.

Awareness in novel technological fields is assumed to arise through developments in *conceptual structure of knowledge, physical structure of knowledge, attraction and legitimacy of knowledge structure, and inter-organizational productivity of knowledge structures.* Awareness draws on the fundamentals of the sociology of knowledge, that focuses on "*the relationship between human thought and social context within which it arises*" (Berger et al., 1967:4). This construct addresses both reality and knowledge; reality "*as a quality appertaining to phenomena … having a being independent of our own volition"* and knowledge "*as the certainty that the phenomena are real and that they possess specific characteristics*" (Berger et al., 1967:1). Hence, awareness centers on the state of mind that considers the interpretive processes concerning the external environment, and its appearance, factual, and objective properties, and simultaneously considers the institutional environment, including its regulative, normative and cultural-cognitive dimension (Scott, 2008). Awareness thus reflects credence of how a future state based on the emergent technology and knowledge structure should be forwarded. Credence is not so much about the final state of use of the technology per se, but more consciousness of those critical properties that needs to be considered in utilizing and forwarding the wider use of a novel technology and the related knowledge base. In this thesis, awareness in novel technological fields is concerned with *consciousness about opportunities of novel technologies and how the new technology challenges existing institutional structures and what is needed to support the emergence of novel technological fields*.

The thesis does not focus on analyzing and describing the content and structure of knowledge per se, but rather focuses on the emergent property of awareness as an interface between the developing information environment and the emergence of knowledge structures. This focus is a response to Walsh's (1995) call for advancing the linkage between the informational environment and knowledge structure. Awareness stresses that there is less a shared template than a certainty versus uncertainty about understanding. In this way the concept of awareness addresses the emergent properties of knowledge structures, the process of change of knowledge structures, and the state of understanding based on the new knowledge structure and its utility, while still in its infancy. The state of awareness thus aims to capture the clarity versus unclarity of interpretation of a novel technological field by individuals and organizations. Awareness highlights the dexterity of individuals and organizations to engage in unconstrained and institutionally disembodied (in relation to a dominant technological and knowledge structures) sense-making (Ghoshal, 1985) in an emergent technological field. In addition, awareness addresses information processing capability (Lord & Hall, 2005).

Awareness can then range in terms of degrees of awareness and in terms of distribution of awareness, ranging from collective macro-cognitive elements in inter-organizational fields (Abrahamson & Fombrun, 1994) to a more fragmented collective consciousness. Although anticipation and expectations focus on future envisioning, awareness includes an understanding of technological opportunities and their value, what is necessary to accomplish these, and what is preventing the emergence of technological fields. In this regard, awareness includes an understanding of the consequences and elements of those properties that enable agency (Emirbayer et al., 1998).

1.4.5. Institutional entrepreneurship

Taking up or enhancing action and common spaces for practitioners (Gibbons et al., 1994), in order to legitimize and create confidence in new technology, arises as interest by actors, that may either benefit or see eventual needs, follow the emerging opportunities. Those actors that come to have a substantial role in disrupting existing institutions and initiating new ones are depicted by DiMaggio (1988) as 'institutional entrepreneurs'. Institutional entrepreneurship is a category of agency. This thesis applies Emirbayer's and Mishe's (1998:970) conceptualization of human agency as *"the temporally constructed engagement by actors of different structural environments—the temporal relational contexts of action—which, through the interplay of habit, imagination, and judgment, both reproduces and transforms those structures in interactive response to the problems posed by changing historical situations".* This perspective addresses the iterative, projective and practical evaluative elements that together in different degrees shape agency (Emirbayer et al., 1998).

Furthermore, although the focus is on institutional entrepreneurs, the thesis considers institutionally constituted properties of agency: *"institutions constrain not only the ends to which their behavior should be directed, but the means by which those ends are achieved. They provide individuals with vocabularies of motives and with a sense of self. They generate not only that which is valued, but the rules by which it is calibrated and distributed"* (Friedland et al., 1991:251). Through the theoretical lenses of institutional entrepreneurship and related agency, this thesis considers how action is interpreted, how it is generative, its methodological nature, and how accurate, all encompassing and inspiring it is. This thesis specifically focuses on institutional entrepreneurship in the emergence of technological fields. Engagement by actors follows different rationales and interests in novel technology, which results in varying degrees of engagement in field-level acts. Field-level acts refer to those acts that intend or come to shape structuring, contexts, and the emergence of a technological field. Institutional entrepreneurship in this thesis attends to *individual-, organizational- or group-level activities that result in non-trivial, trajectory-altering change in the institutional structures of technology fields.*

1.4.6. Institutional contradictions

Although mechanisms of change and development of knowledge structures have been insufficiently explored, this body of research indicates that individual expertise, social interaction, and informational factors, together play an important role (Walsh, 1995). Changes in institutional carriers, such as artifacts, routines, relational systems and symbolic systems, enable institutional change (Scott, 2008). Changes in meaning and knowledge structure include changes of signification. To this extent, the emergence of novel technological fields challenges the prevailing cultural expectations, and shared cognition and beliefs that emanate from isomorphic processes of established knowledge structures (Zilbert, 2008). This generates institutional contradictions. Institutional contradictions entail cultural and material conflicts, appearing as struggles between rational communication and rationalized systems[3] (Friedland et al., 1991:259). Institutional contradictions can arise from the legitimacy that undermines functional inefficiency, adaptation that undermines adaptability, intra-institutional conformity that creates inter-institutional incompatibilities, and isomorphism that conflicts with divergent interests (Seo et al., 2002:226).

In this thesis, institutional contradictions are considered as inter-institutional incompatibilities between actors and departments within organizations, as well as between organizational fields attached to a technological field, resulting in incompatibilities of field logics in directing and guiding productive exploration and exploitation.

1.5. Key assumptions

The thesis takes a philosophical approach which is consistent with Heidegger (1962); where 'being' is a crucial aspect that requires integration into all aspects of study. Heidegger is critical of the social sciences, that fail to give due regard to the importance of 'being' and what constitutes 'being'. Addressing this concern, this thesis follows this important insight and brings it into the realm of emerging technological fields. To further ground this perspective in the realm of technology, the thesis draws on the recent philosophical works of Bernard Stiegler (1998) concerning technology and time. Stigler treats technology as the horizon of human existence. He therefore emphasizes the importance of studying the genesis of technology as the genesis of being 'human' and its temporality. From this perspective, the relationship between technology and being human is not clear. Particularly it is the question of who is the subject and who the objective that is unclear. It is this co-evolutionary process between actors and technology that is at center in this thesis.

1.6. Structure of the dissertation

The thesis is structured as follows. In chapter 2, a literature review and theoretical framing of the thesis is outlined. Chapter 3 presents the methodology and research setting employed in the empirical study. The empirical analysis of the emergence of four technological filed in Finland is presented in chapter 4, including a cross-case analysis and synthesis on emerging technological fields. Based on the case study, the cross-case analysis, and extant literature, chapter 5 develops propositions regarding the macro-level emergent properties in the development of novel technological fields. Chapter 6 then develops propositions on micro-level

[3] This argument originates from Habermas (1979).

emergent properties and the factors that contribute to individual awareness, and how awareness is related to institutional entrepreneurship. A synthesis of findings of the empirical study, the limitations of the study, theoretical and methodological implications, and practical implications, are presented in chapter 7.

2. LITERATURE REVIEW AND THEORETICAL FRAMING OF THE THESIS

Several streams of literature have explored the emergence of novel technological fields. This thesis draws on neo-institutional theory, literature on the social construction of technologies, and the strategic management literature, in order to frame and develop analytical concepts and conceptual models for studying technology field emergence. Together these literatures provide complementary findings on social and cognitive mechanisms (e.g. Hedström & Swedberg, 1996), enabling conditions, properties of emergence (Kozlowski et al., 2000), and rationales for action within emerging technological fields. They also offer evidence and theory on the properties and social mechanisms that constrain and impede knowledge-exploration and exploitation activities, and the emergence of novel technological fields.

The literature review and the theoretical framing of the thesis are organized into three separate sections. This first section introduces organizational field theory and the central institutional mechanism identified in organizational institutionalism, and thereafter reviews the relevant research on technological fields. The second section outlines an institutional analysis of technological fields and presents a synthesis of the recent literature on field-level socio-cognitive dynamics, specifically addressing macro to micro-level properties including institutional contradictions. The third section takes a micro-level perspective, framed through the outlined analytical frameworks in section two, for studying technological fields as inter-institutional structures. Existing research on the emergence and development of institutional entrepreneurship and awareness, and the influence of institutional contradictions on micro-level agency in emerging technological fields is then presented. Together these three sections form the theoretical base and analytical lens that guides the empirical analysis of this thesis.

2.1. Research on organizational fields

Fields have, to an increasing level, been considered as the unit of analysis by researchers attempting to explain both endurance and mechanisms of isomorphic change (DiMaggio & Powell, 1983), and common meaning systems and social structures. The original framing of organizational fields by Powell and DiMaggio (1983) draws attention to how organizations are bound and directed by a common meaning system, and action by actors that participate more frequently and fatefully around a common unity (Wooten et al., 2008:131). Institutions then influence behavior by providing *"stability and meaning to social life"* through rules, norms and cultural-cognitive beliefs (Scott, 2008:48). In this regard, institutions guide action and interaction in specific situations, contexts, and within organizational fields (Scott, 2008). These institutional mechanisms create homogeneity of organizational structures and organizational behaviors in a domain that follows the *"rituals of conformity of wider institutions"* (DiMaggio et al., 1983:150).

2.1.1. Institutional logics and governance structures

The neo-institutional analysis of organizations literature theorizes that action follows mimetic, coercive, and normative forces (DiMaggio et al., 1983). To account for isomorphism organizational field theory outlines elements that constitute fields, such as logics, governance, and social structure. Friedland & Alford (1991:248) define *institutional logics,* as a *"set of material practices and symbolic constructions which constitutes a field's organizing principles and which are available to organizations and individuals to elaborate"*. Institutional logics follow Weber's (1978) theoretical framing of value spheres that incorporate a *"pattern of action and ways of life that are defended as 'rational'"* (Townley, 2002:164). This framing is close to the essence of what March and Olsen (1998:951) term 'logic of appropriateness'; incorporating the idea of *"human action as driven by rules of appropriate or exemplary behavior, organized into institutions"*. Institutional logics are here referred to as *"the cognitive maps, the belief systems carried by participants in the field to guide and give meaning to their activities"* (Scott et al., 2000:171). Institutional logics represent the interpretive schemata that actors hold of the principles of organizing, and the prevailing evaluation criteria that actors draw upon (Greenwood et al., 1996). Logic of actors thus refers to the institutional logic that actors situated in specific organizational fields base their action upon. Previous literature has identified processes of institutional change of logics to include transpositions, collision of logics, and bricolage (e.g. Douglas, 1986; Garud et al., 2003).

Governance structures refers to *"all those arrangements by which field-level power and authority are exercised involving, variously, formal and informal systems, public and private auspices, regulative and normative mechanisms"* (Scott et al., 2000:172-173). Governance structures may range from the more self-organizing to the hierarchical type of structure. They may include regulatory structures and self-enforcing mechanisms that shape the organization of a field. Governance structures, together with institutional logics, form conceptions of control in, for example, markets (economic policies) and industries (Fliegstein, 1990). They range from sector/industry-specific regulatory structures to the more broader societal policies that shape the organization of action (Barnett & Carroll, 1993; Scott, 2008).

Institutional change of organizational fields occurs through shifts in institutional logics and governance structures. Institutional change at the field-level can hence be analyzed by giving attention to structural changes of fields such as (1) changes in relations between existing organizations, (2) changes in boundaries of existing organizations, (3) the emergence of new populations, (4) changes in field boundaries, and (5) changes in governance structures (Scott et al., 2000:24-25). Pressure on, and the deinstitutionalization of, institutionalized norms and practices emerges through functional, political and social sources (Oliver, 1992). Researchers have studied the enabling social mechanisms of institutional change by addressing interest, agency, and legitimacy (Dacin, Goodstein, & Scott, 2002). Institutional change of fields varies in terms of profoundness of the shift. Campbell (2004) distinguishes evolutionary change from revolutionary change, as when few compared to several dimension of an institution change. These two types of institutional change process are driven by different dynamics. Profound institutional change includes changes in several of the relevant dimensions of an institution, and respectively the institutional arrangements that emerge from this change do not resemble those of yesterday. Profound institutional change is then, by character, multi-level and discontinuous, incorporating new rules, governance mechanisms, logics, actors, meaning, new relations among actors, modified population boundaries, and modified field boundaries (Scott et al., 2000).

2.1.2. From organizational to inter-organizational fields

Although the way that organizational fields was framed in earlier times did not explicitly make distinctions between levels or hierarchies of fields, later theory work has separated organizational field mechanisms from inter-organizational or supra-organizational higher levels of field mechanisms (Friedland et al., 1991). This distinction considers how institutional fields are constituted by nested multiple organizational fields, and that fields can be hierarchically layered so that several organizational fields are constituted by higher field logics, for example widely diffused logics of societies (Friedland et al., 1991). This opens up an avenue for analyzing institutional change as emerging from the structure itself through the contradictions arising between fields. This said, Friedland et al., raise cautions about field-level hierarchies in that *"no institutional order should be accorded causal primacy a prior"* (Friedland et al., 1991:241).

Inter-organizational field-level mechanisms have been considered by studying conflicting logics and contestations in emerging organizational fields (e.g. Hoffman, 1999a; Purdy et al., 2009; Thornton & Occasio, 1999b), the evolution of inter-organizational collaboration in novel technological fields, and the shifting prevalence of attachment logics of the emerging field

(Powell, White, Koput, & Owen-Smith, 2005). Studies on institutional change and the emergence of organizational fields have thus engaged in exploring the influence of different actors and their respective logics on patterns and processes of field emergence. By paying attention to conflicts and inter-organizational relations, theoretical developments on organizational fields have returned to the initial ideas of framing of field described by Bourdieu (1971; 1984), in which the field incorporates *"the space of the relations of force between different kinds of capital"* (Bourdieu, 1998:35) [4]. The above shows that research on organizational fields has advanced theoretical developments and empirical studies of both organizational and inter-organizational field-level structures and mechanisms. This framing has allowed a multitude of directions and studies of different collective meaning systems within industries, technological fields, and public sectors to develop.

2.1.3.Review on research on technological fields

A conceptualization of technological fields that is similar to organizational fields has been presented by Garud et al. (2002) in their study of institutional entrepreneurship and the sponsorship of a common technological standard for the Java platform by Sun Microsystems. As standards enable they also constrain the activities a larger community of firms and developers of a technology. This initial framing attends to the negotiated character of both meanings of artifacts and patterns of interaction in a product market domain. The study focused on the *"institutional environment that governs the pattern of interaction"* around a technological system (Garud et al., 2002:197). Institutional environments, in the case of Java, included public policy regimes, regulatory instruments, and mechanisms for venture capital financing. Their study then explored *"different sources of legitimacy ... and underlying norms of community interaction"* in the emerging field of Java software technology (Garud et al., 2002:197). This initial framing of technological fields draws mainly on four literatures: (1) organizational institutionalism, (2) the social construction of technology (3) the research stream on technological paradigms and the trajectories perspective, and (4) the strategic management literature. The roots of this 'socio-cognitive' framing of technological fields, and the linking between the four streams of literature, can be traced back to Garud and Rappa's (1994) elaborations on a socio-cognitive model of technology evolution. The work of Garud et al. (2002) sheds light on mobilization challenges, maintenance challenges, and contradictory

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[4] Bourdieu developed an action theory that gives attention to practice, habitus[4], and the distribution of the four forms of capital - social, cultural, symbolic, and financial capital. In Bourdieu's cultural sociological concept of fields, necessity is imposed on agents and the field. These necessities oppose agents and institutions to struggle. Action is then defined by the constellation of the different forms of capital.

pressures in the emergence of technological fields. As this work frames technological fields as a form of organizational field, I identified four additional streams of research that have made theoretical developments and studied technology field emergence, evolution, and field-level shifts, from complementary but distinct perspectives.

The first additional stream of research has focused on innovation networks and the emergence of technological fields. This research is also grounded in the neo-institutional organizational sociology stream. These field-level studies have highlighted the imprinting effect of initial exploration activities (Powell, Koput, & Smith-Doerr, 1996; Powell et al., 2005), and how both public research organizations and firms are crucial for the linking of actors in order to enable inter-organizational coordination of parallel and supportive activities (Gulati, 1995; Venkatraman & Lee, 2004). This innovation network approach draws attention to how innovation is embedded in networks, and how these networks are formed and subsequently evolve. In this respect, this stream of research provides additional understanding on agency, interest, and field-level action in emerging technological fields. These studies have provided valuable clues on the mechanisms of increased information and confidence and its effect on both direct, and the propensity for indirect, tie formation among distinct actors in innovation and novel fields (Powell et al., 2005).

The second additional stream of research focuses on sectoral systems of innovation (e.g. Malerba, 2004; Malerba et al., 1996). This takes the system at industry-level as the unit of analysis for studying technology field dynamics. This literature has shed light on how the emergence of technological fields and industries are dependent on national institutional structures and forces. From this perspective, the emergence of technological fields appears to emanate from knowledge and learning networks that evolve and develop from existing national technological communities and predominant national industries (Montobbio, 2004:65). Recently, Geels (2002; 2004) has made advances for integrating sociological and institutional perspectives into the innovation systems literature by articulating a socio-technical framing for analyzing the emergence of what he terms 'socio-technical regimes and systems'. Geels has positioned the socio-technical systems as the unit of analysis, embracing elements that are involved in the production, diffusion, and use of technology. This framing addresses the interplay and coordination between different rather autonomous actors, so called multi-actor networks, in a socio-technical regime (Geels, 2004). Socio-technical regimes closely resemble technological paradigms and provide attention structures for those actors who are engaged. Paradigms then emerge and evolve through technological trajectories. To conclude, this stream of research, which considers differing rationales of actors in socio-technical systems and shows the central processes in the co-evolution of technology and society, has made conceptual advances for analyzing the emergence of technological fields.

The third approach, conceptualized as the triple helix model of industry, science and government interaction, is closely related to the innovation systems framework (Etzkowitz et al., 2000). It theorizes that the transformation of dynamics of technological change is due to current ongoing shifts towards a knowledge-based economy. This stream of research has subsequently introduced a more open analysis of the transitions of innovation systems, in which the roles of university, industry, and government are unspecified and emergent by character compared to previous more stable and settled phases (Beesley, 2003; Etzkowitz et al., 2000). This conceptualization thus addresses current institutionalized roles of actors in innovation and the emergent dynamics of shifts in innovation structures.

The fourth additional stream of research that has addressed technological fields is the social construction of technology stream (Pinch et al., 1987) and the closely associated actor-network theory (e.g. Callon, 1986; Latour, 2005). These literatures emphasize the role of agency, interpretation, and struggles (Klein et al., 2002) in shaping, making sense and negotiating the formation of new technologies. Both sets of literature consider how and why power and rationalization, and sense-making by distinct groups of actors, is located and drawn upon in a field. In the social construction of technology stream, emergence is depicted as an adaptation processes by users of technology, as strategies by those involved for developing a technology to improve its adaption and penetration, and the organization and diffusion of new organizational forms. In this regard, framing reflects the central ideas from Giddens' structuration theory concerning the production and reproduction of structures as communicative intents (Giddens, 1978:118).

To conclude, previous research has highlighted how technology fields consist of multiple, temporally distinctive, relational contexts (Emirbayer et al., 1998), with respective interests and agency. This property of technological fields has been attributed to originate from the divided roles and institutionalized logics (Thornton & Ocasio, 2008) of research, technology development, innovation and commercialization. Previous research has thus considered technological fields as constituted by universities, research institutes, industry, and government actors with respective institutional logics and governance structures. It is then technological paradigms and trajectories that provide guidance for coordinating activities between distinct actors in innovation within a predominant technological field. As technological opportunities emerge, they challenge current field logics and governance structures. Previous research has thus concluded that actors are constrained by the lack and the ambiguity of guidance structures. In this respect, emerging technological fields become interpreted differently and translated to action and non-action by distinct actors. Additionally, it has been argued that entrepreneurial actors, especially newcomers, face legitimacy constraints when engaging in emerging fields (Aldrich et al., 1994). Due to these constraints, it has been theorized that new fields emerge through niches that increasingly gain a foothold and finally overturn established technological fields (Geels, 2004).

Previous research has thus developed valuable and rich descriptive material on the processes of technology field emergence, evolution, and shifts. These studies indicate that technological fields should be analyzed as inter-organizational structures. However, less attention has been given to specifying and distinguishing the central institutional elements of technological fields. Only a few studies have explicitly studied emergence, evolution, and shifts of common meaning systems within technological fields (Garud et al., 2002). The basis for compliance, for order, and the shared field-level logics in technological fields, have thus far, not been given adequate attention from an neo-institutional sociological perspective. As a result, the specific mechanisms of institutionalization of technological fields and the carriers[5] of the institutional fabric of technological fields have been poorly studied. To conclude, research aimed at developing, analyzing, and testing propositions on the emergence, evolution, and shifts of technological fields from an institutional perspective has been absent. This is due to the lack of the systematic and comprehensive theoretical and analytical framing of technological fields within the organizational institutional stream of research.

2.2. Theoretical framing of technological fields as inter-institutional structures

This section sets out to frame an institutional analysis of technological fields. This framing is important for advancing both methodological work and empirical research in order to understand better the institutional isomorphic mechanisms and specifics within technological fields compared to other types of institutional fields. To this extent, the social and cognitive mechanisms that enable and retard emergence, and the evolution and shifts within technological fields, are addressed in this thesis. To frame technological fields as organizational fields, this section pays attention to key components of organizational fields, which were identified by Scott (2008) as the cultural-cognitive system and the relational system. The first sub-section thus reviews the relevant literature on the common meaning structures of technological fields,

[5] Carriers is here referred to as the medium which transports the basis of order with its constitutive schemata, expectations, and the regulative rules (Scott, 2008).

including boundary infrastructure, evaluation routines, and technological paradigms and trajectories. Sub-section 2.2.2 then draws on the structurational model of technology (Orlikowski, 1992) in order to conceptualize institutional mechanisms in technological fields. The structurational model of technology proposed by Orlikowski (1992) is first presented. This model is then used as a conceptual guide for framing a structurational model at the field level. In this way, technological fields are conceptualized as inter-institutional structures. This framing is important because it allows connection of the structuration analysis of technology (Barley, 1986; Orlikowski, 1992) with the institutional analysis of organizations (Scott, 2008). Although this connection is precisely what Barley and Tolbert (1997) have suggested, their focus was on micro-level interactions between institutions and action.

To develop analytical tools for studying the emergence of technological fields, it is important to distinguish general field structuration processes and deinstitutionalization processes. Institutional carriers of technological fields are thus categorized and presented. Thereafter, the recent literature on institutional contradictions and the processes of deinstitutionalization of technological fields is introduced. This analytical framing enables us to advance an institutional analysis of the emergent socio-cognitive properties in novel technological fields, such as awareness and institutional contradictions, and to study how they are actualized at the individual, organizational, and field level.

2.2.1.Collective meaning structures in technological fields

Based on the structurational model of technology, an institutional theoretical framing for studying technology field emergence is developed. The framing starts by giving attention to the institutional properties of technological fields. This framing provides a basis for conceptualizing the emergence of technological fields as a process of institutional change.

Boundary infrastructure

Technology, in addition to being embedded and institutionalized within the structure and practice of daily life and work, holds institutional properties that are enacted through a boundary infrastructure (Bowker & Star, 1999). The concept of boundary infrastructure refers to a working and information infrastructure that *"serves multiple communities of practice simultaneously"* (Bowker et al., 1999:313). An information infrastructure is a system of classification and standards that enables work within, and between, organizations (Bowker et al., 1999). A boundary infrastructure reflects the social and moral order arising from categories and is upheld by multiple communities attached to a technological field. These classification and categorization structures hold the character of an invisible force, as they are often *"not able* *to be interpreted by outsiders"* (Bowker et al., 1999:xxx). In use, these structures become taken for granted, indisputable, and inescapable (Bowker et al., 1999). These information infrastructures may also partly disappear in the communities actively pertaining to the structure. In this case a boundary structure then functions as a coordinative structure, and has a material force that *"appears always and instantly"* (Bowker et al., 1999:3).

When classifications become standardized, they gain traction for institutionalization and increasing transportability (Star & Ruhleder, 1996). *"Classifications systems are one form of technology"* (Bowker et al., 1999:290), that at the field level appear as codified knowledge, standardizations, and developments of codebooks (Cowan, David, & Foray, 2000). Rosenberg (1982:143) includes similar arguments, describing technology as *"a knowledge of techniques, methods, and designs that work, and that work in certain ways and with certain consequences, even when one cannot explain exactly why"*. Technologies, when formalized and standardized, allow organizing knowledge exploration and exploitation activities in a distributed manner without always reinterpreting and renegotiating standards, design principles and norms among those developing and using technology. This is true for both those technologies that enable production, development, research, and service work, and those that come out of production processes. The properties and elements of infrastructure direct human agents, and influences and shape the subsequent institutional properties of technological fields. In this regard, technologies attach institutional mechanisms to sectors and organizational fields.

This reasoning resonates with the work of Phillips, Lawrence & Hardy (2004:635) on discourse and institution, in where they define institutions as *"products of the discursive activity that influence action"*. However, in their discursive perspective, discourse is produced through text, not action or artifacts. Technologies hold distinct characteristic that make them unique in terms of an institutional carrier (reach) and for discourse production. For technologies, discourse is produced through texts, objects, and action. Technological objects (the built structures), their materiality and symbolic meanings structured in standards and classifications (Bowker et al., 1999:39-40), allow thoughts and action to transfer accessibly across distances and time. Technologies then function as an interface for meaning construction. Though action and practice, compared to text, are less able to travel across distances, technology as a temporally stabilized relationship between practice and object includes a strong diffusion mechanism. The permeability of objects across distances and social contexts, embedded in the categories and codes, enables diffusion of both the 'hardware and software' of technologies (Orlikowski, 1992). Technologies hold properties resembling formal language structure. However, technologies as boundary infrastructure are less bounded by traditional language communities and related cultural barriers. Skills formation institutions (Thelen, 2004), such as universities and schools and international and national professional training programs, are important for diffusing and directing development of boundary infrastructure.

Evaluation routines

The objectifications and classifications that develop drives the field and sector to institutionalized practices and communication forms, or in what Barley (1990:65) articulates as *"the practices that have the normative force of taken-for-granted assumptions and cultural blueprints for action".* This indicates that actors become 'blind' over time to spot how they are related to other actors and other levels of the emergent state of a technological field. These social and cognitive processes unfold over time, as a technology develops, into beliefs, artifacts and evaluation routines (Garud et al., 1994). Evaluation routines include the notion of *"a shared reality that strongly shapes the direction of future technological change"* (Garud et al., 1994:344) that have spread among actors in a technological field that guide exploration. Routines merge and settle into the expectation structure of actors who participate in a technological field (van Lente et al., 1998). In this way, evaluation routines translate into logics of practice, governance, and actor identities in a technological field.

Why then insist on characterizing and arguing for the field-level institutional properties of technology? What are the benefits and possible trade-offs? In treating technology as holding institutional properties, it follows that technological change is bound by previous technological structure and respective rules, norms and cultural-cognitive beliefs. Information infrastructures get embedded and learned as part of membership (Star et al., 1996). The state of technology can thus be distinguished as emergent and held together by negotiated and settled articulations among, and between, groups (Pinch et al., 1987). The institutional structure of norms, rules and cultural-cognitive elements emerges, constrained by previous technological structures, through the engagement of agents in the interpretation and translation of novel technological opportunities. This construction and structuration process includes contestations between the prevailing institutional properties of technology and novel technological opportunity. Prevalent organizational and technological archetypes thus direct interpretations and framing of emergent technological fields by guiding sense-making, exploration and exploitation strategies, and the application and use of logics of technology. Barley (1986) identified how technology occasions different organizational structures by altering institutionalized roles and patterns of interaction. These encounters and confrontations between prevalent and emergent technological institutions then evolve through processes of transformation, bricolage (Garud et al., 2003), and socio-technical regime shifts (Geels, 2002).

Although boundary infrastructure addresses the role and importance of artifacts in innovation, evaluation routines provide insights on cognitive structures and elements that shape sense-making and awareness of new technologies. Together they provide theoretical arguments for analyzing meaning, interpretation and sense-making and sense-giving in novel technological fields. This suggests that boundary infrastructure and evaluation routines are central appearances of the regulative, normative, and cultural-cognitive structure that shapes action around emerging technologies.

Technological paradigms, trajectories, and dominant designs

Technologies show distinct properties (in comparison to human centered institutions[6]) of increasing returns[7] that lock them into distinct designs and trajectories in a technological paradigm. Technologies are complex hierarchical systems, which include a "*nested hierarchy of technology cycles"*, that take form as dominant designs (Murmann & Frenken, 2006:944). The nested hierarchy takes in the hierarchy of inclusion and hierarchy of control that are found in dominant designs (Murmann et al., 2006). Increasing returns are features of a technology and its social context generated by large set-up or fixed costs, learning effects, coordination effects, and adaptive expectations (Arthur, 1994:112). The process of increasing returns includes properties of unpredictability, inflexibility, non-ergodicity, and potential path inefficiencies (Arthur, 1994:112-113). Although these externality effects explain the lock-in of technological design, they also present the generative mechanisms that contribute to the institutionalization of technological structure, and closure of discussion around the technology. When technologies lock-in they become non-politicized (Pierson, 2004), taken for granted, and objectified as naturally existing. Technological paradigms, trajectories, and dominant designs thus function as mental maps (Arthur, 1994; Denzau & North, 1994) in guiding further exploration and exploitation around technologies. Technological trajectories and dominant designs also provide identification of organizations and individual work with a technological field and the related boundary infrastructure (Bowker et al., 1999) and evaluation routines (Garud et al., 1994). Equally, opportunities are interpreted through the structure of existing technological paths. It is mainly when technologies or technological systems within a paradigm break down (Perrow, 1999) or become contested by radical technological change (Christensen & Rosenbloom, 1995), that the institutional structure of technological fields becomes visual and apparent. The profoundness of change has been linked to radical changes in the knowledge antecedents of innovation and in consequences and possibilities opened up by radical innovations (Murmann et

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[6] Those that do not include technological objects in social interaction.
[7] Increasing returns are specific properties of institutions.

al., 2006). At the structural level, radical change is linked to change in upper levels of the design hierarchy that prevails in a technological field (Murmann et al., 2006:944). In profound technological change, this is important as new meaning, new relations, new actors, and related field-level boundary modifications emerge endogenously.

The process of profound institutional change of technology fields, include mechanisms and properties of not only translation, but also of radical change, creative destruction, and construction. In this respect, the nested hierarchical structures of the dominant design (Murmann et al., 2006) and related practices, are altered in profound ways, including transformation of traditions of practice and communities of practitioners (Constant II, 1987) that participate and dominate the prevailing boundary infrastructure of a technological field. The 'culture of technology', the values, ideas and institutions that have emerged around the prevailing structure (Hughes, 1987) are then challenged. Although the role of users has been emphasized for early market construction, the ability of the institutional structures attached to technology to adapt to novel and more radical technological opportunities is far more problematic, according to research on user innovation. Paradigmatic change (Dosi, 1982), and the emergence of innovation and production structures to a novel technological logic and governance structure, are bound to face challenges. These innovation challenges have particularly been emphasized by introducing concepts such as architectural innovations (Henderson & Clark, 1990), radical innovations (e.g. Abernathy & Clark, 1985; Abernathy & Utterback, 1978), and disruptive technologies (Christensen et al., 1995). Together these address the challenges of incumbent firms to attend to novel technological opportunities. These challenges are explained by the embeddedness of firms' technical and production competencies (Abernathy et al., 1985), architectural knowledge (Henderson et al., 1990), and value-networks (Christensen et al., 1995). With emerging technological fields, the boundary infrastructure, the competence base, and the designs structures are altered. Embeddedness of organizations in these knowledge structures then constrains, to different degrees, their ability to recognize, interpret, and evaluate new technology. The fundamentals on which they base their decisions and strategies for exploring and exploiting emergent technological fields is therefore constrained by the existing knowledge structure, resource allocations, and supportive structures that follow the prevailing technological paradigm.

Alignment, connecting and re-connecting parts of the social structure in productive and novel ways, does not emerge easily. Hidden and institutionalized rules of interaction, how to read a situation and 'commitment structures' (Greif, 2006), surface when emergent and dominant technological institutions confront and mesh into each other. In these situations, actors easily draw on existing technological structures for interpreting emergent novel technological opportunities. Technological paradigms (Dosi, 1982), or so called technological guideposts (Sahal, 1981), provide attention structures. They provide projections as technology and design trajectories (Dosi, 1982), and technology avenues, (Sahal, 1981) that guide interpretations and the framing of technological change. With technological paradigms and related technological trajectories, explorative and exploitative activities tend, over time, to gain formal properties and become embedded in social structures (Granovetter, 1985; Tushman & Anderson, 1986). In this respect, technological fields are institutionalized, and it becomes increasingly difficult for actors to spot and value novel technologies. It is the more radical departures from prevailing technological trajectories that are particularly left aside. Thus, the enduring forces of institutional carriers that eliminate alternatives are set in motion (Clemens & Cook, 1999). Paradigmatic change shifts the relationship of technology and innovation as the overall design is reconsidered. When new technologies emerge that challenge existing industries or provide opportunities for the creation of the new, the institutionalized structures of knowledge exploration and exploitation are challenged.

2.2.2. Technological fields as an arena of multiple institutional logics

The duality of technology, conceptualized and theorized in the structurational model of technology proposed by Wanda Orlikowski (1992), indicates the institutional characteristics of technology:

> Technology is the product of human action, while it also assumes structural properties. That is, technology is physically constructed by actors working in a given context, and technology is socially constructed by actors through the different meanings they attach to it and the various features they emphasize and use. However, it is also the case that once developed and deployed, ***technology tends to become reified and institutionalized,*** losing its connection with the human agents that constructed it or gave meaning, and it appears to be part of the objective, structural properties of the organization. (Orlikowski, 1992:441) [8]

This important observation seems to have gone rather unnoticed by technology and organizational scholars. Despite its high impact, the key message of the duality of technology, that *"technology is the product of human action, while it also assumes structural properties"* (Orlikowski, 1992:406), has been surprisingly unable to redirect rigor and focus in research on the relationships and interactions between technology, human agents and institutional properties. The inability of the productive reach of the structurational model arises from a separation of institutional properties and technology in the model, and an undeveloped and non-

[8] Highlighting and italic does not appear in the original article.

theorized application of the structurational model of technology at a field level. As a construct, technology incorporates institutional elements, which, if excluded from the analysis of technology structuration and change, leaves much unexplained or even erroneously interpreted. Although a multitude of institutions enable society, technologies seem to hold institutional characteristics, properties, and generative mechanisms that need to be analyzed differently from other forms and types of the institutions of human society.

Technology, through practice and use, becomes institutionalized (Orlikowski, 1992). Practices that gain stability around a technology reflect institutional response. However, technology itself, in its form and with distinct knowledge characteristics, also holds institutional properties that influence the value construction of the organization of practices of knowledge. This suggests that, technologies and related activities hold strong elements for acquiring institutional properties that are in use. Nelson and Sampat (2001) have proposed social technologies as the routines that together with physical technology constrain and limit choices around a technology. These routines are built into relations and structures through which actors become entrenched with technology. Although this notion is conceptually attractive, it does not pay attention to the role and ability of the technological artifact to impose equally behavior that is institutional, taken for granted, and expected through rules, norms and cultural-cognitive beliefs.

Actors in a technological field hold different interactions with the technology. They are situated in different organizational fields. Technological fields incorporate a multitude of communities with distinct logics and forms of governance, such as industry, research institutes, universities, government agents, public sector actors, ministries, professional associations, industry and trade associations. These multiple organizational fields, with distinct institutional logics and forms of governance (Scott et al., 2000), interact and connect through boundary infrastructure, evaluation routines, and technological trajectories. Through this act of bridging, they shape and construct the technological interface of artifacts, which at the same time, feeds back and organizes structures around technology. In these processes, organizational fields acquire institutional properties that constrain and facilitate action and practice in a technological field. Through emergent technology field structures the technological fields embraces technology-specific logics and logics of innovation and the respective governance structures that function as inter-organizational field-level patterning institutional structures. *Logics of innovation* include assumptions about the roles of specific actors in innovation. *Technology specific logic* follows the dominant design and trajectory theme and includes assumptions about organizations and use of technology, assumptions about customers, and about production, manufacturing, and the distribution of technology.

Exploration and exploitation activities around novel technological opportunities are complex and dynamic social and technological construction processes. These processes incorporate a diverse mix of actors and a multitude of explorative and exploitative activities often dispersed in time and space. The propensity for engaging in knowledge exploration and exploitation changes with the gradual emergence of a field. Activities in novel technological fields advance field-level emergence at different levels. For example research and development work enable micro-level emergent processes to form as organizations engage in exploring and exploiting novel technologies. Field-level action by, for example, government, and professional and industry associations, shape and influence macro-level conditions in the emergent field. Although the former contribute to knowledge spillover and learning effects at the field level, the latter attend to action that facilitates and enables collective meaning structures, field-level awareness, and legitimacy of the novel field.

Exploration is often an endeavor into the partly unknown and often seems to be not directly guided by strict rules and goals regarding outcome. Certain actors in society have been tasked with the role of taking on more explorative work, such as universities and research institutes. In addition, research and development department of larger corporations are traditionally viewed as repositories of riskier 'blue sky' research. Others have been identified as primary exploiters and those whose role is to take economic benefits from new technological knowledge; for example industry, firms and government. In this regard, innovation has been pictured as the interaction between exploration and exploitation of knowledge, where distinct actors hold specific roles, but are loosely connected in generating value from technological knowledge (Bozeman & Rogers, 2002). The actors that interact in production and *"joint use of a body of information"* (Rogers & Bozeman, 2001:27) as producers and users of knowledge, have been conceptualized as 'knowledge value collectives' (KVC). The framing of KVC centers on the loosely interactive process around capturing value from novel technologies. However, field-level conditions are also shaped by legislative bodies (e.g. sector ministries and the parliament), actors involved in standardization (e.g. industry and standards associations), actors facilitating the use of technology (e.g. new energy technology promoting agencies), and actors who fund and promote research and technology development (e.g. government funding agencies and venture capital firms). Equally, there are actors that, in other more indirect but equally important ways, contribute to shaping designs, technological paths, and technological fields, such as customers, NGOs, and government procurement and taxation policies. Equally, more indirect mechanisms in knowledge exploration and exploitation exist that make information visible, accessible and transferable, example education, seminars, patenting databases, academic papers, media, and the internet. In addition, there are actors not directly engaged in the activity of innovation, but rather who facilitate and enable the condition of innovation, the use of technology, and the emergence of novel technological fields.

The interaction between and among these diverse set of actors, and the emerging technological field seems, in important ways, to shape exploration and exploitation activities of novel technological knowledge (e.g. Cohen, Nelson & Walsh, 2002) and the subsequent emergence of novel technological fields. The multitude of action strategies and rationales provide direction, pace, and logics for interaction which influences the abilities of actors, the speed of take up, and the penetration of novel technological knowledge in industries and society. Guidance for action in exploration and exploitation then follows from material practices, symbolic constructions, and projections of technology evolution that are shared through the design and the shared technological trajectory.

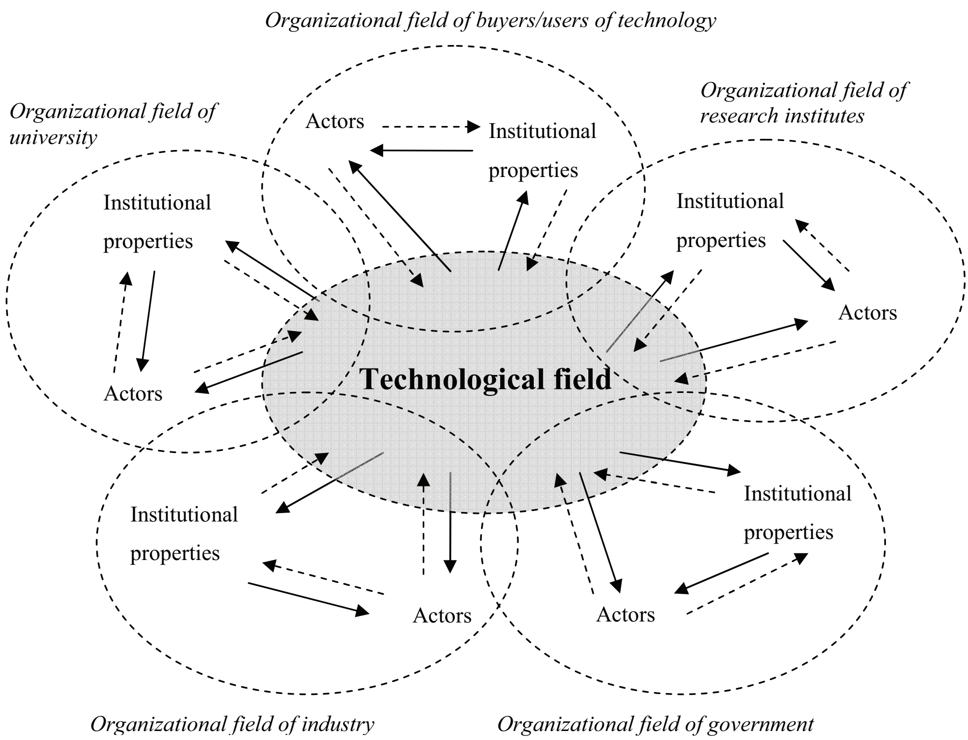


Figure 2-1 A conceptual model of technology fields as inter-institutional structures

Technology at the field level links and connects distinct organizational fields, such as the organizational field of university, research institutes, the industry, the government, and buyers/users of technology (see Figure 2-1). This inter-organizational field around a technology then holds institutional properties that align and coordinate distributed practice, sense-making, and work. These interfaces produce distinct structures and contradictions that influence the socio-cognitive dynamics in a technological field and the subsequent properties of institutional change. This framing builds on the structurational model of technology (Orlikowski, 1992) by extending it to the field level (Figure 2-1). This way of framing technology is richly informed by the increasing analytical and valuable theorizations by institutional scholars, particularly the stream of literature on institutional analysis of organizations (e.g. Powell & DiMaggio, 1991; Scott, 2008) and historical institutionalism (e.g. Pierson, 2004; Thelen, 2004). The presented framing adds to these theorizations and provides avenues for exploring the specific institutional properties and characteristics of technologies at the field level.

The outlined structurational model of technological fields solves previous shortcomings described by both evolutionary economics and organization technology scholars in that it analyzes and explains technological change. Here I refer to technological change that contests and puts pressure on prevailing institutionalized practices in sectors and fields and related organizational structures. This framing of the issue addresses situations described as architectural, paradigmatic, radical, or disruptive technological change. Scholars have conceptualized this process by arguing that these situations introduce institutional change and require social innovations (Lundvall, 1988). However, these conceptualizations have been far more descriptive rather than theoretical articulations, investigations, and the production of a dialectic stream of discourse of the underlying mechanisms of institutional change. By identifying and adding to the structuration model of technology, according to which technology holds elements of boundary infrastructure (Bowker & Star, 1999) and evolution routines aligning work within sectors and fields, I include the generative mechanism that explains and gives technologies their institutional characteristics. Technological fields incorporate a multitude of communities attached to technology through distinct practices and logics enacted within boundary infrastructure. These produce distinct types of structures, stages and contradictions that enable institutional change processes within technological fields.

2.2.3. Institutional carriers of technological fields

The previous section presented key elements and properties of common meaning structures of technological fields and the central institutionalization mechanisms of knowledge structures. In this regard, the section outlined the central institutional properties of technological fields. These institutionalized structures appear as regulative rules, laws, and sanctions, normative certifications and accreditations, and as cultural-cognitive common beliefs, shared logics of action, and as isomorphism (Scott, 2008). To productively study institutional change requires attention to, and identification of, the central institutional carriers of technological fields. This is important for disentangling the previously presented elements of the institutional fabric of technological fields in order to generate a comprehensive institutional framing. The categorization of institutional carriers into symbolic systems, relational systems, routines, and artifacts, as described by Scott (2008), is used and modified to frame this synthesis of the institutional carriers of technological fields. Four distinct institutional carriers are specified: (1) the symbolic system including standards, classifications, and regulation, (2) the relational system including discourse, social capital, and legitimacy, (3) organizational- and inter-organizational routines including practices and skills, and (4) technological artifacts including objects. These carriers are then, in accord with Scott's conceptualization of regulative, normative and cultural-cognitive pillars as distinct dimensions and elements of institutions, used orthogonally to distinguish different ontological assumptions regarding the social reality used with regard to the rationality of actors (Scott, 2008:62) in and towards a technological field .

	Pillars		
	Regulative	Normative	Cultural-Cognitive
Technological artifacts (carriers: objects)	Objects complying with mandated specifications and standards	Objects enforcing meeting conventions and standards	Object possessing symbolic value
Organizational and inter-organizational routines (carriers: practices and skills)	Protocols Standard operating procedures	Role definitions	Evaluation routines and problem-solving strategies
Symbolic system (carriers: standards, classifications, and regulation)	Rules in technological fields Laws targeting technology production and use	Values Expectations	Categories Typifications Schemata
Relational systems (carriers: discourse, social capital, and legitimacy)	Governance system Power systems	Regimes Authority systems	Field logics Identities

Table 2-1 Institutional carriers of technological fields (modified from Scott (2008))

Technological artifacts as institutional carriers

Technology as an artifact reflects the physical appearance and formalization of technology as an object. It draws attention to objectified properties and qualities of technology that has to be, or has been, agreed and settled upon. Although some objects become naturalized (Latour, 1987) and gain symbolic value, this does not apply to all. The physical appearance of technological artifacts, the senses, and knowledge base needed and used to interpret technological artifacts, has an impact on organizational and institutional properties surrounding technology. Artifacts help *"recall and recombine distinct pieces of knowledge offering a tangible form of access to help translate knowledge from one community of experts to another"* (Murray & O'Mahony, 2007:1007). The ability to appropriate value from developing technology and innovating (Teece, 1986) is dependent on the tangibility, visibility, and interpretability of technological objects. Technological artifacts differ in terms of their interdependency and systemic character, ranging from the more autonomous to more systemic and complex structures. They also vary in the maturity of technology and the institutionalization of technological and organizational structures. Although artifacts enable, at the same time they constrain and enforce compliance with specifications, standards and conventions. These artifact-related properties have an impact on how technologies are objectified and organized, as well as how technologies invite or exclude the participation of actors; for example users, policy, industry or science. The interface between artifacts and actors forms a distinct knowing structure for actors engaged with the technology. In this regard, technological artifacts are central elements of boundary infrastructure.

Organizational and inter-organizational routines as institutional carriers

The second institutional carrier of technological fields distinguished as a separable element with its specific social-cognitive dynamics, addresses the practices, routines and skills that enable and sustain widely shared thoughts and norms. Practices, skills, and routines in a technological field are held together through the tacit and explicit knowledge base of a technological field. Technological fields are carried by organizational and inter-organizational routines that produce and reproduce boundary infrastructure, evaluation routines, and problem-solving strategies. To this extent, practices, routines, and skills in a technological fields enable interaction between action and structure (Giddens, 1976).

Symbolic system as institutional carrier

Standards, classifications, and regulations reach out to the technological field and guide inter-organizational interaction. This third carrier provides the rules, categories, typifications, and schemata that actors in a field draw upon. In this regard, the boundary infrastructure of a technological field becomes embedded as a symbolic system that directs expectations in the field. It functions as the carrier of actors' interaction, experience, and the base for examining emergent technological opportunities. Boundary infrastructure enables genre repertoires (Yates & Orlikowski, 1992) that actors may draw upon and provide attainable design strategies for productively facilitating the institutional change of technological fields (Hargadon et al., 2001).

Relational system as institutional carrier

These carriers of technological field are reflected in the discourse, role definitions, power relations, governance structures, and logics in a technology field. Together they direct and pace the relational system of the field; this functions as the fourth carrier. The properties of the relational system can be studied by giving attention to the construction, development, and use of technology in a field.

Together, the four institutional carriers of technological fields enable the basis of compliance and order in the field. The separation between the symbolic system and the technological artifact is similar to the distinction between the cultural matrix and exemplars that together form a technological paradigm that was described by Van den Belt and Rip (1987). By considering these elements as institutional, and adding the binding mechanisms of the relational system and routines, provides a strong institutionally-based conceptual framing for analyzing socio-cognitive dynamics and the emergence of novel technological fields.

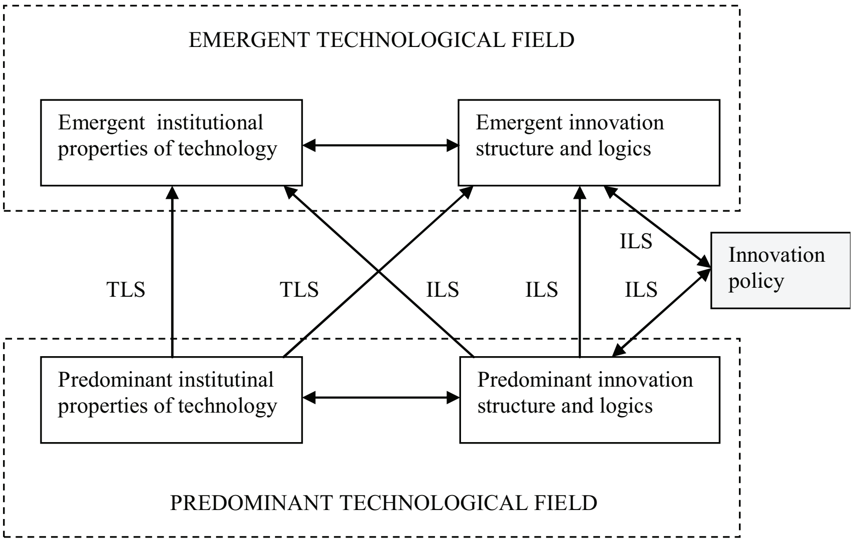
2.2.4. Institutional contradictions in emerging technological fields

The emergence of technological fields is critically dependent upon solving emergent institutional contradictions. This section sets out to review the literature on institutional contradictions in emerging technological fields, and to frame a conceptual model for analyzing contradictions at the field level. This initial framing draws on previous theoretical and empirical work on institutional contradictions within the organizational field literature (Seo et al., 2002). Seo et al. (2002) employ a dialectical perspective [9] for conceptualizing institutional contradictions. They identify four distinct mechanisms that trigger institutional contradictions within an organization, among individuals, and groups, in response to contextual influences. Institutional contradictions emerge as legitimacy that undermines functional inefficiencies, adaptation that undermines adaptability, intra-institutional conformity that creates inter-institutional incompatibilities, and isomorphism that conflicts with divergent interests (Seo et al., 2002:226). Institutional contradictions take form as conflicting logics (Purdy et al., 2009) and competing rationalities (Townley, 2002) around an emerging organizational field. Institutional contradictions appear both within organizations, at the organizational-field level and at the inter-organizational-field level. It is therefore the actions of actors, including

[9] A dialectical perspective is suitable for analyzing institutional change processes and is guided by the principles of social construction, interconnectedness of social patterns, contradictions, and praxis (Seo et al., 2002).

individuals, organizations, and social movements, and the human praxis enacting institutional contradictions that enable institutional change (Seo et al., 2002).

A technology field gains institutional properties through dominant design, standardization, and the diffusion and embeddedness of boundary infrastructure. These manifests as logics of innovation and technology specific logics at the technological field level (see Figure 2-2).



TLS = Shift in technology-specific logic
ILS = Shift in logics of innovation

Figure 2-2 Model of technology field-level shifts

Institutional contradictions then arise as (1) alternative technological archetypes that delegitimize existing archetypes emerge, (2) when radically more efficient or substantially value increasing technological innovations start formalizing through demonstrations and innovations, and (3) when new innovation practices are taken up by actors within one or several organizational fields in a technological field. Competing logics may subsequently arise in relation to: (1) contested roles in innovation conceptualized as a *shift in logics of innovation*, and (2) contested technology design, practices, and use appearing conceptualized as a *shift in technology-specific logics*. New logics of innovation may also arise in response to changing agendas and assumed roles of innovation policy, informed by past experience or in reaction to foreseen challenges. Transpositions, collision of logics, and bricolage (Garud et al., 2003), have been proposed as conceptualizations of the process of the emergence of new logics and the shift from one logic to another. From this perspective, new logics have been pictured to emerge through nesting and alignment at multiple levels. New technologies enter existing technological fields both endogenously and exogenously. The reproduction of institutional logics of technological fields and the carriers are then disrupted and challenged through emergent human praxis, creating institutional contradictions.

The emergence of novel technological fields challenges the legitimacy of current action and existing technologies. Individual and organizational social and cognitive attachments to dominant technologies and technological trajectory are thus contested. In this respect, the emergence of technological fields is bound by the institutional contradictions that come about. The predominant knowledge structure and its institutionalized appearances hampers actors from productively interpreting value and opportunities, envisioning productive innovation strategies, and questioning current roles and practices in innovation and commercialization. As novel fields are, by character, under organized and pluralistic, they create inconsistencies in response to novelty (Goodrick & Salanzik, 1996). Only when new fields gain a foothold and have strong enough attachment with prevalent institutionalized structures of technological fields (Hargadon et al., 2001) do institutional isomorphic mechanisms gain traction for institutional change. This indicates that the emergence of novel technological fields is inhibited, not necessarily due to the lack of learning itself, but rather, by how this learning is constrained and channeled by the established institutional structure.

To frame analytical units for analyzing institutional contradictions in emerging technological fields, I draw on the initial conceptualization developed by Seo et al. (2002) on institutional contradictions, and consider these at the organizational-field level. The review indicates two distinct mechanism and analytical units of institutional contradictions in emerging technological fields; institutional contradictions due to a *lack of legitimacy* of novel technological fields, and institutional contradictions that result from *incompatibilities of predominant technology field-level logics* in directing productive exploration and exploitation. Although novel technologies promise more value, opportunities, and efficiencies, legitimacy and pervasiveness of the institutional carriers of the dominant technological trajectory undermines the functional inefficiencies. Incompatibilities of field logics in directing and guiding productive exploration and exploitation arise from inter-institutional incompatibilities between actors and departments within organizations, as well as between organizational fields attached to a technological field. The legitimacy constraints of novel technological fields inhibit the attraction and commitment of actors to the emerging technological field. Incompatibilities of dominant institutional logics inhibit sense-making and emergence in novel technological fields. The literature on legitimacy and organizational fields has mainly addressed social mechanisms as central sources of legitimacy constraints and contradictions. By attending to incompatibilities in prevailing institutional logics, the framing presented in this thesis considers how interactions between social and cognitive properties create institutional contradictions. Contradictions also create shifts from passive conformity to reflexive activities that distance actors from prevailing institutional structures and enable increasing imagination (Seo et al., 2002), and conscious departures from technological trajectories and routines. To conclude, institutional contradictions explain both resistance and emergence of agency for institutional change, materialized as inhibited emergence and institutional entrepreneurship in emerging technological fields.

2.2.5. A synthesis of technological fields as inter-institutional structures

This section has framed an institutional analysis of technological fields, and developed and adapted analytical frameworks and conceptual models from organizational institutionalism for studying the emergence of technological fields. Technological fields incorporate collective meaning structures that are manifested in boundary infrastructure, evaluation routines, and technological paradigms. Technological fields are continuously interpreted and enacted upon through several distinct sub-organizational field logics, such as universities, research institutes, firms, and government agencies. Thus, technological fields may be depicted as an arena of multiple institutional logics. They are a particular form of organizational fields with inherent institutional carriers. It is specifically the materialization of technology and a shared technological frame, institutional properties of technology, and the dynamics of technological change that are brought into the center of the analysis when addressing technological fields. This means that institutional carriers of technological fields, including the symbolic system, the relational system, organizational and inter-organizational routines, and the technological artifacts together through normative, regulative and cultural cognitive properties are the key elements of technological fields. These properties are subsequently to be considered when analyzing technological fields. To account for the institutional properties of technological fields, it is equally important to consider those central logics of technological fields that become institutionalized and are challenged by emerging novel technologies. It is here asserted that technological fields are centrally organized through technology-specific logics and logics of innovation. These two logics together then account for institutional contradictions in emerging technological fields.

These frameworks and analytical models outlined in this section are used in the case study as tools for analyzing the four cases of emerging technological fields, and for directing the cross case analysis. This framing also enables one to explore further the micro-level socio-cognitive dynamics and micro-macro processes in emerging technological fields. The following section reviews research on awareness and institutional entrepreneurship and considers the emergent properties that arise at the micro-level, together with the developed macro-level emergent properties of institutional contradictions and emergence of technological fields that were conceptualized in the previous sub-sections.

2.3. Theoretical framing of micro level socio-cognitive dynamics in emerging technological fields

The previous section outlined a framework for studying technological fields from an institutional perspective, and specifically considered macro to micro situational mechanisms (Hedström et al., 1996) of technological fields. Because of the lack of evolution in theorization on institutional properties and institutional dynamics of technological fields, the literature has not addressed, in detail, micro-level and micro to macro dynamics, including action-formation mechanisms and transformational mechanisms (Hedström et al., 1996) of technological fields. Recent research has indicated how emergence and channeling of institutional entrepreneurship in emerging fields influence dynamics and structuring of field emergence in important ways.

To untangle action-formation and transformational mechanisms, and to establish a micro-level analysis in technology field emergence, this section addresses awareness, institutional entrepreneurship, and institutional contradictions. It is important to focus on awareness and institutional contradictions as they together capture the emergent and variously distributed meaning structures and contestations in institutional logics around emerging technological fields. This framing is a response to Munir and Phillips (2005:1665) call for *"a more 'institutional' understanding of the phenomena"* that leads to widespread adoption of radical new technologies. In addition, technological fields provide a productive context for studying institutional change, as the institutional structure can be traced and categorized by both its knowledge and organizational structural properties. This allows one to study more carefully the underlying socio-cognitive mechanisms of field emergence.

The first sub-section starts by addressing the general properties of micro-level socio-cognitive dynamics in emerging technological fields. Then, drawing on this analytical work, an initial conceptualization of awareness in emerging technological fields is presented. Sub-section three outlines the properties of institutional entrepreneurship and respective distinct properties in emerging technological fields. The two subsequent sections then outline initial assertions on awareness and institutional contradictions in relation to institutional entrepreneurship. This theoretical framing and initial synthesis on the socio-cognitive dynamics in emerging technological fields provides important analytical tools for the empirical study.

2.3.1. Initial contention of micro-level socio-cognitive dynamics in emerging technological fields

Those factors that constitute and enable agency and interest of actors around prospective and emergent technological opportunities in technological fields, specifically when technologies challenge prevalent innovation and technology specific logics, are distinct and different from those related to organizational and cultural innovations which have been widely considered by institutional scholars. It is the relationship between technology and human agents, (Orlikowski, 1992) and the high complexity of these interrelationships, that provide the distinct characteristics of mobilization, structuration, and institutional change of technological fields.

Actors situated in various organizational fields within a technological field hold distinct roles in relation to their inclination of how much they are informed by the past, inclined to the present and toward the future (Emirbayer et al., 1998:962). During disruptive technological change key technological features, embedded in artifacts, practices, and standards are challenged. Disruptive technological change here refers to those situations when new technologies disrupt prevalent and institutionalized technological and innovation structures in a technological field, and enable the emergence of novel fields. Disruptive technological change creates contradictions and struggles in the inter-institutional system (Friedland et al., 1991) around both technology and the roles of actors. In this regard, agency and interest are not pre-given in situations of disruptive technological change, but rather, contemporaneously emergent with those technological opportunities that were triggered (Hargrave & Van de Ven, 2006). As the knowledge base is challenged during more radical technological change situations, actors become differently aware and informed of emerging opportunities due to their temporal structural agency. It is then the multiple temporally distinctive relational contexts (Emirbayer et al., 1998) of predominant technology fields that provide interpretation of disruptive technological opportunities among actors.

Although agency and the orientation of interest should be productively linked during times of incremental technological change, disruptive technological change imposes challenges, particularly in relation to how agency and interest is constituted. Agency and interest around disruptive technological opportunities does not simply emerge through firm strategic behavior, but rather through those communities of practice that, in a continuously evolving context of technological fields, become influenced by factors that trigger agency and interest towards disruptive technological opportunities. In this respect, agency and interest may be triggered in any organizational field that constitutes technological fields. Similar suggestions have been made by (Etzkowitz et al., 2000) through their 'Triple Helix' model. Their framing introduces a more open analysis (compared to the main evolutionary economics and innovation systems literature) of the transitions of systems of innovation, where the roles and interfaces of university, industry, and government (representing the helices) are unspecified and emergent. The Triple Helix model assigns a critical role to creating and redefining expectations and for the roles assumed by actors in innovation systems. Although this approach addresses the level of the nation state, the theoretical arguments fit equally well at the technology field level. The subsequent emergence and productive take-up of novel technological opportunities are then dependent on how able the triggered agency and interest in the novel technology and respective communities of practice are in gaining traction and legitimacy between the 'helixes'. Equally critical in shaping productive emergence are the issues of how boundary spanning activities are organized, and how these trigger alignment between organizational fields for exploring and exploiting novel technological opportunities.

Several perspectives have evolved for analyzing and explaining shifts in technology field-level social structures. Those that indicate most promise and relevance to advance a socio-cognitive framing of technology field emergence include; studies focusing on the discourse around novel technologies (e.g. Phillips et al., 2004), studies on how legitimacy of actors and technologies form (e.g. Barley, 1986; Douglas, 1986; Rao, 1994; Suchman, 1995), and studies on the role of agency in directing and advancing the structuring of novel technological fields (e.g. Garud, Hardy, & Maguire, 2007; Garud et al., 2002; Rao et al., 2000). These studies examine questions such as, how different mechanisms intervene, enable, and produce distinct processes of institutional change in technological fields, and how these properties structure and pace the emergence of novel fields. In this regard, these studies have focused on explaining shifts at the field level, despite mimetic, coercive and normative isomorphic mechanisms (DiMaggio et al., 1983) of dominant technological fields. This literature has increasingly considered issues of agency and interest by studying institutional entrepreneurship (Garud et al., 2007; Garud et al., 2002) and social movements (Lounsbury et al., 2003; Rao et al., 2000). The focus in these studies has been on advancing understanding of the role of institutional entrepreneurs and social movements in shaping and advancing the institutionalization of new organizational forms around novel technologies (Garud et al., 2003).

In summary, research on socio-cognitive elements in technology development has shown how asymmetries of inputs from distributed agency to an emerging technological field, and its technological path, are valuable and form a *'creative synthesis'* of a collective (Garud et al., 1994:281). This process has been conceptualized as *'bricolage'*, where producers and users interact with each other around an evolving technology design with their specific organizational field lenses, rather than a breakthrough type strategy, where producers introduce full scale solutions directly to the market without the iterative process of bricolage (Garud et al., 2003). The productivity and success of technological field emergence is then grounded in a settled division of focus and institutionalized distributed organization of exploration and exploitation of technology knowledge value. To conclude, the review has considered the central socio-cognitive dynamics in emerging technological fields, and the interaction between the macro and the micro-level properties and mechanisms that enable, direct and constrain the emergence of technological fields. Specifically, it has more carefully considered institutional entrepreneurship and from where this emerges, and what processes appear to be critical for better understanding how institutional contradictions subsequently unfold and can be reduced. Although previous research has successfully explored social dynamics of emerging technological fields and institutional entrepreneurship, little is known about the cognitive dynamics in these settings and the role of awareness in institutional entrepreneurship. The following section thus outlines an initial theoretical framing of awareness, institutional entrepreneurship, and institutional contradictions in emerging technological fields, while concurrently giving consideration to micro-level socio-cognitive processes.

2.3.2. Awareness in emerging technological fields

New technologies that have the potential for wider diffusion and penetration in industries and society create uncertainties. Milliken (1987) distinguishes between environmental uncertainty in effect, state, and response uncertainties. Uncertainty within a technological field increases through, for example, deregulation in industries and with disruptive and competence destroying technologies (Christensen et al., 1995; Koka, Madhavan, & Prescott, 2006). Uncertainty results in the inability to *"accurately access the external environment"* (Dickson & Weaver, 1997:405). The ability to interpret, make sense, and comprehend how a technology domain is emerging, and how to productively respond to emerging opportunities, is conceptualized here as awareness. This conceptualization draws on the phenomenological accounts on the socially constructed nature of knowledge (Berger et al., 1967), perception and thoughts (Schutz, 1982), and how knowledge is made explicit in social interaction. The concept of awareness centers on the state of mind that considers the interpretive processes about the external environment (appearance, factual, and objective), and simultaneously considers the institutional environment, with its regulative, normative and cultural-cognitive carriers (Scott, 2008). From this perspective, awareness attends to macro-cognitive elements in inter-organizational fields (Abrahamson et al., 1994). Awareness is closely related to the concept of cognitive similarity, defined as *"beliefs about the types of issues perceived to be important, how such issues are conceptualized and, perhaps, alternative approaches for dealing with such issues"* (Simsek, Lubatkin, & Floyd, 2003:433).

In uncertain environments, non-hierarchical and non-market forms of exchange organize themselves as networks (Powell, 1990). Several scholars have highlighted gaps in the current literature relating to the relationship between network and interpretive processes (Ibarra, Kilduff, & Tsai, 2005), and the necessity to study awareness and interaction (Glaser & Strauss, 1967). By giving attention to the cultural-cognitive pillar (Scott, 2008) *this thesis treats the inter-organizational network and the technological field as an interpretive structure.* Though actors hold a subjective interpretation, shared meaning is a prerequisite for individuals to take collective action (Stevenson & Greenberg, 2000). This framing of the issue extends, to the organizational-field level, Dafts & Weicks (1984) work on organizations as interpretive systems. Organizational fields incorporate a common meaning system which is incorporated by actors who frequently interact with one another (DiMaggio et al., 1983). These common meaning systems are necessary for logics of a field to emerge.

Awareness among multiple actors is advanced by the ability of these actors to make abstractions and share meaning (Bandura, 1986). The emergence of awareness requires actions and effects to be proximate in both time and space (Bandura, 1986). Awareness is formed through sense-making processes that link connections and anticipate trajectories of complex and ambiguous phenomena and contexts (Klein, Moon, & Hoffman, 2006). Recent research has provided theoretical accounts on how cognitive similarity is strengthened among structurally embedded actors that engage in continuous sense-making (Simsek et al., 2003). Awareness is then formed through the use of schemata and thought patterns. The use of schemata and enactment are elements of sense-making that *"resides in inter-subjective processes among actors"* (Weber & Glynn, 2006:1643). The emergence of novel technological trajectories requires field-level *"expectations about success of continuing work within this cluster of heuristics – expectations that must be embedded in the subculture of the technical practitioners"* (Van den Belt et al., 1987:140). To conclude, the concept awareness does not address the thought structure of the individual, but rather focuses on the *relative certainty* versus *uncertainty* prevailing at the field and community-level, as well as at the individual level, about emergent technological fields. To this extent, awareness is asserted as structurally embedded (Granovetter, 1985) and addresses the cultural-cognitive pillar (Scott, 2008) of technological fields.

2.3.3. Institutional entrepreneurship and technology field emergence

The previous section outlined central micro/macro-level socio-cognitive dynamics in emerging technological fields. This section focuses more carefully on micro-level agency, specifically institutional entrepreneurship in emerging fields. First, through a review, the central elements of institutional entrepreneurship are identified from the literature on organizational fields. Thereafter, a review of the current research and distinct properties of institutional entrepreneurship in emerging technological fields is outlined.

General accounts on institutional entrepreneurship

Agency and interest that enable institutional change of organizational fields may develop between any actors and in any organizational field within an inter-organizational field. Previous research has reported how central actors (Lounsbury et al., 2003; Morrill, 2007), bridging/mediating actors (Maguire et al., 2004), and peripheral actors may equally function as change agents in field-level institutional change (Greenwood & Suddaby, 2006). Institutional entrepreneurship and social movements emerge due to inefficiencies in providing organizationally efficient behavior to a present contextual situation within prevalent institutional structures (DiMaggio, 1988; Fliegstein, 2001; Greenwood et al., 2006; Seo et al., 2002). Further, inter-institutional incompatibilities and conflicting interest (Seo et al., 2002), social injustice, or the lack of an identity space for individuals and interest (Rao, Monin, & Durand, 2003) function as triggers for social movements and institutional entrepreneurship. Although conceptualized as change agents, agency and interest is also embedded in prevailing institutional logics (Giddens, 1984; Thornton et al., 2008). Institutional entrepreneurs and social movements become organized and engaged through institutionalization projects (DiMaggio, 1988:15), professional associations activities (Greenwood, Suddaby, & Hinings, 2002), and functional or interest movements (Hoffman, 1999b; Rao et al., 2003). Depending on their position in a current setting, and how they organize themselves as change agents, institutional entrepreneurship subsequently takes on different forms and dynamics (Maguire et al., 2004).

To engage and impact institutional change, institutional entrepreneurs and movements construct practice models, standards and measurement tools (Dejean, Gond, & Leca, 2004; Lawrence, 1999; Lounsbury et al., 2003), take on agency legitimacy enhancing activities (Hoffman, 1999b), and develop membership strategies and inter-organizational collaborations (Lawrence, Hardy, & Phillips, 2002). The effectiveness of institutional entrepreneurship and social movements is affected by successful identity construction and the ability to simultaneously include old and the new identity; referred to as hybridization (Rao et al., 2003). Equally important is how successful institutional entrepreneurs and social movements are in theorizing the need for change and picturing the process of change. For these activities to gain traction it is critical that the interests of diverse stakeholders are translated productively (Maguire et al., 2004; Strang & Meyer, 1993). Development of a stable coalition of diverse stakeholders, through political tactics such as bargaining, negotiation, and compromise, is also critical for advancing productive change activities by these agents (Maguire et al., 2004). Attaching new practices to existing routines and aligning them with values of diverse stakeholders (Maguire et al., 2004) enables effective shifts. In addition, the formation of subsidiary institutions (DiMaggio, 1988:15) and how movement initiation triggers the generation of spin-off and counter movements (Maguire et al., 2004; Rao et al., 2000) is crucial for explaining the effectiveness of institutional entrepreneurship and social movements. To conclude, this review on institutional entrepreneurship in organizational fields shows how institutional entrepreneurship can emerge from several locations in a field, and the different strategies institutional entrepreneurs engage in to facilitate change.

Institutional entrepreneurship in emerging technological fields

The institutional properties of technological fields, such as carriers, logics and governance structures, are distinct in several ways. This is reflected in the socio-cognitive dynamics in technology field emergence. This is why it is important to study and analytically distinguish distinct properties of institutional entrepreneurship in emerging technological fields. A review of the current research on institutional entrepreneurship in emerging technological fields is outlined here. Although this part focuses on the general properties of institutional entrepreneurship in emerging technological fields, the following two sections then explore awareness and institutional contradictions in relation to institutional entrepreneurship in this context.

Agency and interest in research, innovation and technology development is distributed and organized in distinct organizational fields, constituted by university, research institute, industry, government, and mediating organizations. Organizational fields are penetrated by distinct practices and elements that constitute agency and interest with regard to their connection to the field-level innovation and technology specific logics. Just as agency and interest provide projections and evaluations of emerging technological fields, they are equally shaped by emergent technological opportunities. As Emirbayer & Mische (1998:964) note *"the key to grasping the dynamic possibilities of human agency is to view it as composed of variable and changing orientation within the flow of time"*. From this follows that agency and interest in technological fields should be assessed as emergent. By attributing the emergent characteristics of agency, it follows that each organizational field holds the potential for constituting agency and interest in emerging technological fields.

Another important characteristic of emergent technological fields is what Pinch et al. (1987:40-44) term interpretive flexibility. Interpretive flexibility arise from *"different interpretations by social groups of the content of artifacts lead by means of different chains of problems and solutions to different further developments"* (Pinch et al., 1987:42). Callon (1986) provides additional understanding on the negotiated character of emerging technological fields, and highlights challenges which emerge in the translation of an actor's role in emergent technological structures. He develops the concepts of actor worlds and actor networks to theorize the socially constructed nature of agency and interest in technological fields. Interestingly, only few studies have explicitly followed up on this, and studied the social embeddedness of technological change, technology field emergence, and technology field evolution from the perspective of agency and interest (Garud et al., 2002; Garud et al., 1994; Rosenkopf & Tushman, 1994). These few studies have focused on the interaction between organizational/technological communities and technology evolution (Rosenkopf et al., 1994). They indicate that interactions range from non-coordinated self-organizing dynamics (technological determinism) to organized and planned structuring (social construction). Community organizational dynamics appear more pronounced for complex technologies and during times of disruptive change (Rosenkopf et al., 1994). Studies on institutional entrepreneurship-type strategies by firms in open source communities (Garud et al., 2002) and in consumer and end user groups (Munir et al., 2005), have considered how firms gain legitimacy and acceptance for field-wide technologies through intelligent value construction and by shaping institutional change.

As the locus of innovation and technology-specific logics shifts, certain actors become more prone and able than others to redirect and enable action effectively within an emergent novel technological field. In this respect, the assimilation and capacity, also reflected through physical, social and economic context, become important in taking stock of emerging technological opportunities (Solo, 1967). However, those actors more capable, with respect to the novel and emergent knowledge structure, often confer less capacity and legitimacy to facilitate the emergence of a field (Aldrich et al., 1994).

To summarize, institutional entrepreneurship is considered here as individual- or group-level activity that results in non-trivial, trajectory-altering change in the institutional structures of technology fields. By 'non-trivial', the study refers to change in the evolutionary trajectory of a given technological field. Thus, institutional entrepreneurship attends to trajectory-altering change in technological fields, change that would not emerge by itself.

2.3.4. Awareness and institutional entrepreneurship

The previous section presented the key elements of institutional entrepreneurship in emerging technological fields. Essential questions that have remained unexplored include: the role of awareness in enabling and directing institutional entrepreneurship, and how institutional contradictions impact institutional entrepreneurship in emerging technological fields. This section addresses the first question by attending to action-formation mechanisms, and initial explanations arising from the relationship between awareness and institutional entrepreneurship. In this regard, this section addresses the different socio-cognitive mechanisms for action in emerging technological fields, and distinguishes institutional entrepreneurial action from isomorphic behavior. This distinction is also useful for the development of initial analytical tools that account for varying institutional contradictions, and how these are reflected in the role of institutional entrepreneurship and productive strategies to enable the productive structuration of emerging technological fields.

With respect to awareness this thesis considers the cultural-cognitive pillar of institutions (Scott, 2008) and takes a socio-cognitive perspective for interpreting agency, interest, and action in emerging technological fields. Awareness here is both a situational property and an individual action mechanism. This thesis therefore addresses the collective interaction of individual action mechanisms and situational mechanisms (Hedström et al., 1996) in emerging technological fields. Awareness is a critical factor for productive learning (Bandura, 1986). As institutional responses are critical for accounting for actors responses to change in a specific setting, actors should not solely be treated as 'cultural dopes'(Hall, 1981). Equally, one should consider actors as intelligent and rational, being able to interpret, understand, and make sense of novelty. For individuals this means addressing more final causes of knowledge locus and their *"abilities to create and absorb knowledge"* (Felin & Hesterly, 2007:204), and for organizations this means the ability to shift from single-loop to a double-loop learning (Argyris, 1976). Awareness thus refers to the different degrees of abilities to attend to external influences. In this regard, awareness enables action and agency that may not resonate and fit with previous institutional logics. Although a low level of awareness reflects situations in which actors engage in single loop learning, a high level of awareness includes the processes of double loop learning (Argyris, 1976). As those actors that hold lower awareness of emerging technological fields follow dominant logics, those with higher awareness may conflict with these logics, thus being more aware of novel opportunities. Therefore, actors that hold higher awareness of emerging technological opportunities and challenges are not only basing their agency and institutional entrepreneurial action on legitimacy, but equally on expertise and network position. Clarifying this relationship between awareness and institutional entrepreneurship is critical as it draws attention to how action, agency, and interest are temporally embedded processes, shaped and guided by interaction and reflections of past, present, and future. Temporality of agency and awareness is enacted through iterational, projective and practical-evaluative processes (Emirbayer et al., 1998). From this perspective, framed consciousness is guided by the reflective interaction of future needs, current norms and practice, and underlying interests. The emergence of technological fields is, in this respect, pictured as a process of *creation and shaping of an awareness landscape around novel technologies*.

While awareness relates to cognition, the rationale that an actor *should act* in response to an emerging technological field emanates from the *significance* that the emerging technological field imposes on an actor. Significance here addresses the different degrees of relevance for acting. In conditions of low significance actors have no rationality to respond to external influences, while high relevance relates to situations when actors have rational motives to act in response to external influences. By addressing different degrees of awareness and significance allows one to distinguish underlying socio-cognitive bases for action around emerging technological fields (Figure 2-3).

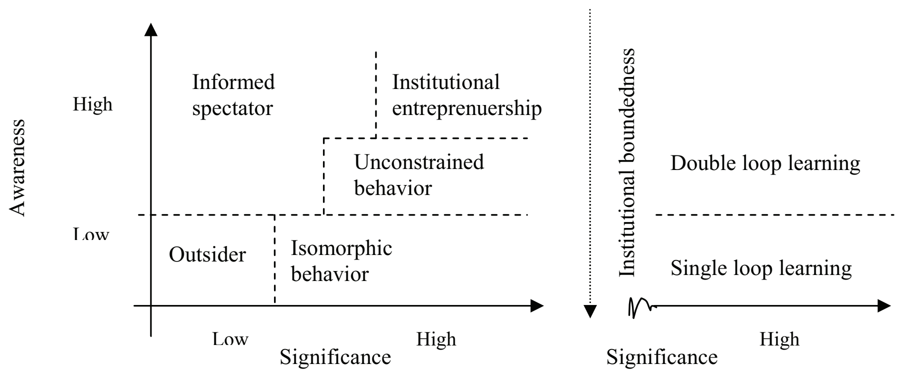


Figure 2-3 The awareness and significance matrix of action in emerging technological fields

This means that although actors respond with action to emerging technological fields, their awareness differs with respect to whether they base their action on current institutional logics or are able to attend equally to the emerging technological field and engage in double loop learning. This is important because isomorphic behavior, unconstrained behavior, and institutional entrepreneurship, perceive, attributes, and enacts (Weick, 1995) the role of other actors differently. Actors responding with isomorphic behavior contend the predominant technology specific logics and innovation logics with predefined roles of actors. Unconstrained behavior by organizations and individuals follows the principles of double loop learning - here referred to as institutionally disembodied action. These actors are capable of questioning current technology-specific logics and innovation logics and to learn and change existing assumptions and practices. Informed spectators are then actors with high awareness for which the emerging technological field does not create significance that would engage them in active engagement in the emerging field. Those actors that have a low awareness to the emerging field and for which the field does not have significance for are considered outsiders. Institutional entrepreneurs are actors capable of reflecting emergent technology specific and innovation logics and respective novel and non-specified roles of actors. To this extent, institutional entrepreneurs and actors hold, to a greater degree, an unconstrained and institutionally disembodied ability for sense-making on emergent technological opportunities compared to other actors.

To summarize, this review provides analytical concepts and tools for looking at and distinguishing institutional entrepreneurship from other behavioral traits of actors in emerging technological fields. This is in line with recent suggestions that consider institutional and rational forces as *"alternative sources of structure and behavior"* (Townley, 2002:164). This review has subsequently distinguished between different types of actors and behavioral traits and their position towards emerging technological fields by specifically addressing awareness. Institutional entrepreneurship is here then depicted as agency that incorporates high levels of awareness and to which the emergent technological field appears as a significant arena in which to engage in action. This analytical framing provides an avenue to consider awareness and agency from an institutional perspective, and to explore those mechanisms that create and direct them. The empirical part of this thesis explores these social-cognitive dynamics and develops, from the subsequent cross case analysis, propositions on awareness and institutional entrepreneurship.

2.3.5. Institutional contradictions and institutional entrepreneurship

The institutional carriers of technological fields directs our attention to the different formalized and taken for granted roles of actors in innovation, for example, by attributing 'naturally' who should engage in exploration and who should engage in exploitation. Institutionalized roles around technologies differ a lot across technologies and technological fields. Technology, thorough artifacts, practices and standards, functions as an interface and aligning mechanism of meaning construction. At the same time, through their enactment with technology, actors function as the interface between distinct organizational fields. Actors tend to commit and represent their respective institutional perspective in situations of technological change and institutional change. A similar conclusion was drawn by Marx (1937:199) who stated: *"Technology is what mediates between man and his relationship with the external, material world. But in acting upon the material world, man not only transforms it for his own useful purpose…but he also, unavoidably, engages in an act of self-transformation"*(formulation by Rosenberg, 1982:39).

Actors who engage in institutional entrepreneurship, depending on their position, organizational membership, and background in the prevailing and emergent technology field, hold different degrees and forms of legitimacy. Individual actors and their positions and roles are, to varying degrees, embedded and legitimized in the prevailing technological field and in the emergent technological field. These conditions of embeddedness of agency impact individual actor's ability to shape emergence. This process of self-transformation creates inertia for the evolution of field-level interfaces such as boundary infrastructure and evaluation routines. The interpretations and action strategies around novel technological fields, and emergent technology use characteristics, are bound by established institutional structures of predominant fields and related innovation structures. Focusing on field-level phenomena, specifically awareness and institutional contradictions, provides stronger analytical tools for explaining and understanding the institutional processes of maintenance, reproduction, and change in technological fields.

Technological fields start decomposing as technological artifacts, symbolic systems, relational structures, and practices, develop or are shifted by any of those organizational fields involved. Consequently, institutional properties, both at the technological and the organizational-field level, are challenged. The previous section on institutional contradictions in emerging technological fields identified two key mechanisms of contradictions, *legitimacy constraints* and *inconsistencies in field-level logics*. The distributed infrastructure that provides the emergent character of technological fields is continuously challenged through evolving artifacts, routines, and relational structures. Technology fields, though driven by externalities and feed-back mechanisms into technological trajectories (Arthur, 1989), also always include processes that enable decomposition and fragmentation of the structure. In this regard, technological fields include elements that enable more profound changes, changes of technology paradigms, architectural innovations, and radical technological change at the field level. It is then a matter of how these processes gain traction and the capabilities to develop value from the novel technological opportunities that enable shifts from existing dominant designs to new structural arrangements. The propensity for change, and shifts of technological fields, thus depend on the degree and character of legitimacy constraints and inconsistencies in field-level logics. Legitimacy constraints translate into different degrees and forms of challenges for attracting, for example, visibility and resources. Inconsistencies in field-level logics translate into varying degrees of necessity to engage in double-loop learning (Argyris, 1976) and productive knowledge absorption and creation (Felin et al., 2007). To conclude, institutional contradictions in technology field emergence should thus vary in strength.

Varying degrees of institutional contradictions have been conceptualized and theorized by Seo et al. (2002), which distinguish between conditions of weak and strong non-adaptability of organizational fields. Non-adaptability refers to the degree of embeddedness of institutional arrangements and how tightly coupled they are (Seo et al., 2002). Weak non-adaptability includes gradual shifts in collective consciousness, while strong non-adaptability addresses situations when *"capacity of the existing institutional arrangements to constrain its participants' thoughts and behaviors is strong",* and thus is more disruptive and tends to cause institutional crises (Seo et al., 2002:235).

When institutional contradictions between a predominant technological field and an emerging technological field are less disruptive, institutional entrepreneurs should be much more able to gain traction and attention for conferring change and collaboration. Equally, when institutional contradictions are strong, institutional entrepreneurs should be faced with a substantially challenging context and resistance, or even denial, when engaging in enabling actions. These challenges in strong institutional contradiction situations are, in part, due to inabilities to interpret and attend to critical information *"beyond institutional boundaries",* and also in part, due to less motivation *"to actively respond"* (Seo et al., 2002:235).

In summary, institutional entrepreneurship is challenging in different ways due to the different circumstances and degrees of institutional contradictions present around emerging technological fields. This has implications for the efficiency of strategies of institutional entrepreneurs involved in emerging technological fields and for the question, to what level it is necessary to facilitate field-wide awareness in an emerging technological field. These issues are explored in the case analysis. Building on the findings from each case, and the cross case analysis reported in chapter 5, propositions on institutional contradictions and institutional entrepreneurship are developed in chapter 6.

2.3.6. A synthesis of micro-level socio-cognitive dynamics in emerging technological fields

In this section, an initial theoretical framing of micro level socio-cognitive dynamics in emerging technological fields has been outlined. Awareness, institutional entrepreneurship and contradictions are here asserted as key elements for capturing these micro-level socio-cognitive mechanisms and dynamics. Together these three elements constitute, enable, and constrain agency and interest around emerging technological fields. A central argument is that these constitutive and enabling elements and related micro-level socio-cognitive field dynamics differ from those mechanisms that have been generalized across institutional sociological work on organizational fields in important ways.

Firstly, awareness in technological fields is not only based on the ability to overcome institutionally constrained processes of interest and agency, but is equally driven by the ability to absorb and draw on developments of technological frames and processes that guide knowledge exploration and exploitation. Secondly, addressing the degree of awareness and the level of significance for actors to act in emerging technological fields enables one to distinguishing different action types in these settings; such as: (1) isomorphic behavior, (2) unconstrained behavior, and (3) institutional entrepreneurship. It is here contended that institutional entrepreneurship in technological fields emerges through high levels of awareness and respective high-level significance and relevance for action that the emergent technological field imposes upon an actor or group of actors. Thirdly, while previous studies have stressed the role of institutional entrepreneurs, this framing also considers the action strategies by those influenced by institutional entrepreneurial action. This is important in order to better capture micro-level socio-cognitive dynamics and varying rationales both in terms of awareness and significance that an emergent technological field imposes upon actors. These varying rationales towards an emerging technological field act to influence the ability to impose change and equally affect the efficiency of different strategies of institutional entrepreneurship.

Fourthly, this framing brings out properties that influence the effectiveness of institutional entrepreneurial action and the strategies institutional entrepreneurs may draw upon to productively facilitate the emergence of technological fields. It is argued here that the degree and properties of institutional contradictions an emerging technological field imposes upon existing technology specific logics and innovation logics is what critically determines the opportunities and effectiveness of institutional entrepreneurial action. Subsequently, institutional entrepreneurs are faced with varying degrees and forms of legitimacy constraints and inconsistencies in field-level logics.

To summarize, those factors that constitute and enable agency and interest of actors around prospective and emergent technological opportunities in technological fields, specifically when technologies challenge prevalent innovation and technology specific logics, are distinct and different from those related to organizational and cultural innovations that have been widely considered by institutional scholars to date.

3. METHODOLOGY AND RESEARCH SETTING

The empirical study sets out to explore the emergence of technological fields by attending to awareness, institutional entrepreneurship, and institutional contradictions - central properties that facilitate, constrain, and pattern field emergence. The empirical study addresses the emergence of four technological fields and their materialization through national technology programs in Finland during 1994 and 2005. An exploratory multiple case study research design was considered most appropriate to address the outlined research questions and the phenomena of socio-cognitive dynamics and emergence. The qualitative case study method takes an iterative and inductive research approach for building explanations (Yin, 2003). Qualitative case studies are suitable when the context of the studied phenomena matters in important ways (Eisenhardt, 1989). Qualitative case studies are also good at dealing with complex dynamics and interlinked events and the processes within a distinct contextual situation (Miles & Huberman, 1994). Hence, temporality is better accounted for by qualitative case analyses, also in retrospect (Miles et al., 1994). The case study is then followed by two chapters, which based on the case analysis and extant literature on the observed phenomena, develops propositions on the macro- and micro-level emergent properties around novel technological fields. In this respect, the thesis follows the approach and outlined stages of theory building from cases described by Eisenhardt (1989).

The chapter is organized as follows. Firstly, the framing of the empirical study is outlined, focusing on the general constructs and some key assumptions that guide the study. Thereafter, the research setting of emerging technological fields in Finland and national technology programs are described. Thirdly, the rationale for selecting the four cases is presented. The fourth section, presents the data used and the principles and arguments for using the case method. The firth section outlines how the case analysis progresses, its focus, and the logic of the analysis for both the part that deals with the within case analysis and that which addresses the cross-case analysis.

3.1. Framing of study

The challenge with analyzing cases is that they rely on meanings presented by actors and their interpretations about different situations and phases in a specific context. To support insight and theoretical contribution from the case study, framing of the empirical study is carried out by first outlining the initial scope, the important constructs addressed, and the specific focus of the study. This specification supports the case analysis by providing categories and dimension that are consistently analyzed in the case analysis. This provides logical coherence to single case analyses, and strengthens the cross case analysis, the subsequent development of propositions, and the dialogue with previous research and literature on the studied phenomena and its socio-cognitive mechanisms. A framework supports pattern-matching and the ability to theorize within a chosen theoretical domain (Eisenhardt, 1989; Gibbert, Winfried, & Wicki, 2008); in this case, institutional sociology.

The literature review and the initial theoretical contention suggests that institutional change and emergence are those processes that need to be addressed in order to capture socio-cognitive dynamics in novel technological fields. Research on institutional change as a process have centered on studying the interplay between meanings, action and actors (Dacin et al., 2002). Hinings et al. (2004:304) have proposed a process model to study institutional change at the field level. They identified five overlapping stages of institutional change: (1) pressures for change; (2) the sources of new practices from institutional entrepreneurs; (3) the process of deinstitutionalization and reinstitutionalization; (4) the dynamics of deinstitutionalization and reinstitutionalization; and (5) reinstitutionalization and stability. The empirical study presented in this thesis is founded on this process model, addressing emergence of the technological field, institutional entrepreneurship, awareness and institutional contradictions.

Emergence is the other key mechanism that, in conjunction with institutional change processes, the thesis addresses. To study the emergence of a technological field, some general properties that enable and constrain emergence and the micro to macro and macro to micro dynamics in novel technological fields are identified. The previous chapter identified three distinct elements, awareness, institutional entrepreneurship, and institutional contradictions that impact on the emergence of technological fields in important ways. Together, they address contextual, perceptual, and agency-related mechanisms that are theorized to influence: (1) the capacity for enabling institutional change that promotes field emergence; (2) the easiness versus difficultness of formation of coordinative interfaces that direct, focus, and align knowledge exploration and exploitation in the field; and (3) technology-related creativity, innovation capacity, and problem solving ability around an emerging technological field.

To this extent, distinct phases in emergence of a technological field should become apparent and thereby further enrich the process-oriented approach. Different stages and phases in the emergence trigger actions and non-actions. The empirical study is founded on the assumption that agency and interest shape the construction and take-up of novel technological opportunities, which, within existing technological fields, are disruptive in character. In this regard, the study follows DiMaggio's (1988:11) call for developing *"predictive and persuasive accounts of the origins, reproduction, and erosion of institutionalized practices and organizational forms"*. Equally, the study considers Wooten & Hoffman's (2008:138) call for research to *"investigate the dynamics that lead to field creation and the contextual factors that lead to one field form over another"*.

In addition, the study pays close attention to identified generative properties of emergence and socio-cognitive dynamics in technological fields, specifically those that are explicit in relation to other types of organizational fields. The framing outlined in chapter 2 addresses the multitude of rationales of action around novel technological fields and the 'churning' (Bozeman et al., 2002) of different values and perspectives in taking stock of new technology. By addressing different rationales and logics for action, the framing pays close attention to contextual properties and is focused on developing local rather than global theories on the dynamics of emergent and organized action in organization theory (Friedberg, 1997). This framing also takes seriously the call for addressing sector- and technology-level differences in innovation structures (Malerba, 2004), and the call for explicit comparative studies of emergence of fields (Scott, 2008). The framing also is concerned with where new knowledge reside and takes shape, and how action around novel technological fields takes place as a concurrent process, often outside functional structures. This is important while this 'locality' of knowledge influence establishment of actors and collaborative patterns that may depart from conventional innovation logics and pre-defined roles of actors. This framing therefore also considers the tensions and struggles between actors that appear during technological shifts, and how conflicts among stakeholders are resolved (Scott, 2008; Townley, 2002). Specifically, this action and mechanism around the novel technological fields approach, provides a deeper understanding for what prevents and what enables actors, in different phases with distinct institutional and path history, to engage in field-level activities.

3.2. Research setting

Four emerging technological fields and the related collaborative activities between research, industry, and government in Finland during 1994-2005 are studied.

Governmentally coordinated and managed technology programs emerged during and after the Second World War in several developed countries, for example in U.S., France, and Japan (Hayashi, 2003; Mustar & Larédo, 2002; Shapira, 2001). In Finland the technology program concept emerged in early 1980s with the establishment of Tekes, to intensify collaboration between firms, research institutes and universities, following the example of Japan and Sweden

(Lemola, 2002). Programs were thus to facilitate institutional change in industrial systems, by taking up emerging technological opportunities. In Finland, national technology programs are funded and organized under Tekes, the National Technology Agency of Finland. Public industrial research projects in programs receive funding from 60 to 100% and firm collaborative projects receive funding between 30-50%. Programs range in volume and number of organizations participating. During the 1990s Finland adopted a national innovation system of strategy and a national level strategy aimed towards a knowledge-based society, and was one of the first nations to do so. Accordingly government funding and support for innovation increased. Within the time period of 1990s up until 2004, national technology programs in Finland rose in importance. This meant increasing number of programs, increasing size of programs, and overall development of management practices and support functions of national technology programs (Tekes, 2004). While Tekes thus established itself as the dominant funder of the innovation phase in Finland (Ministry of Trade and Industry, 2003), firms consequently increasingly came to participate in such national technology programs. Although there were industry sector differences, a large share of those organizations that were developing technologies within the different focus areas of a program were inclined to participate in projects within the programs. The assumption for this study is thus that national technology programs gathered most of those relevant, active, and entrepreneurial organizations and individuals in Finland around the emergent technological field at focus. The study of national technology programs provides thus an opportunity to reveal the underlying institutional structures and struggles around emerging opportunities, and the ability to configure these structures and reconstruct them in the context of emerging technological fields in a national context. The study takes a long-term perspective and a longitudinal field research approach on the evolution and changes of innovation structures in emerging technological fields. Thus, both the periods before and after the program are included in the analysis. As programs are often followed by a subsequent program, (and also preceding programs), or some other collaborative activity, these are also included in the analysis. This provides for better accounting of temporal inertia and the rather slow but profound changes of institutions and strategies around novel technologies. This said, the study also pays close attention to the temporality of behavior (Faulconer & Williams, 1985) and change processes (the sequence and order of activities and events (Poole, Van de Ven, Dooley, & Holmes, 2000), and strategic rationality and subsequent behavior) in revealing an understanding of patterns of events and the emergence of technological fields. In this respect the study carefully considers the embeddedness of action around novel technological fields as a means to theorize about change.

The context of national technology programs in Finland is a specifically interesting context for studying the inertial forces and facilitating elements that underlie institutional change in industrial-technological systems. The programs address situations of high uncertainty, with the explicit intent to enhance the functioning of innovation systems. Finnish national technology programs are loosely structured, offering plenty of room for individuals to innovate and seek new solutions. These settings not only provide opportunities and initiatives for the exploration and exploitation of novel technologies, but also for the struggles and averseness for engaging in collaborative activities and participation in technology field development. To this extent, considering emergent characteristics of institutional properties, agency and interest, and innovation networks, should provide further understanding of what enables and inhibits technology field emergence. As this study takes a national level perspective on the emergence of technological fields, global developments of a technological field are not specifically addressed and included in the analysis. Indirectly though, a national perspective addresses how a global technological field may both penetrate and have central elements constructed within the national setting. It is specifically this second alternative of construction and the subsequent global diffusions of elements of an emerging technological field that is studied in more detail in the empirical part of this thesis. Even though the emergence of a technological field at a global level is thus not explicitly addressed, this thesis provides important indications of the nature and complex interaction between the local and the global setting of such emergence.

The chosen empirical setting lends itself well to the study of agency and interest, such as institutional entrepreneurship, awareness, and institutional contradictions in the emergence of technological fields. Finland is often referred to as a good example of a ‘coordinated market economy’, and is also characterized as a social-corporatists policy model (Jepperson, 2002) in which different organizational actors willingly cooperate and coordinate action that goes beyond the realm of traditional market mechanisms (Hall & Soskice, 2001). This makes the study interesting because of the facilitated opportunities and assumed tendencies for interaction. This should provide stronger differences and stronger effects in terms of inertia and struggles versus attraction and action in the emergence of technological fields. By studying emergence of technological fields over time, this study addresses to calls for increasing the understanding of network evolution (e.g. McPherson, Smith-Lovin, & Cook, 2001; Powell et al., 2005). National technology programs and the context of Finland provide a unique opportunity to capture and attend to *evolution of entire networks,* that as empirical studies have remained few (Powell et al., 2005).

3.3. Case selection

Case selection was theoretically driven, aiming for polar types in respect to field-level logic and governance (Scott et al., 2000) and in terms of different challenge the emergent field imposed upon prevalent technology field level logics. Properties of field-level logic and governance were assumed to shape emergent properties and socio-cognitive dynamics around novel technological fields in important ways. The following polar types were therefore included: (1) the degree of market versus non-market properties in the industry sector at focus; (2) the size of the technological field and related diversity of community; (3) the basis of institutional entrepreneurship; (4) the stage of emergence of institutional carriers of the field; and (5) the origin of institutional contradictions in technology-specific and field level innovation logics.

The degree of market versus non-market properties in an existing technological field and the wider industry is reflected in different governance structures and innovation logics of a field and how change is organized. While market based structures, in their pure form, follow the logics of self-organizing and competition for adapting to change, non-market contexts are much more governed by strategic and planned institutional change. These properties of market versus non-market based technological fields are reflected in different socio-cognitive dynamics, for example through the varying roles of demand conditions and user-producer interaction in innovation, and thorough various prospective opportunities imposed by the prevalent ability to appropriate value from innovations. Together these conditions influence the formation of awareness and agency in the varying contexts in important ways. Equally, various forms of institutional contradictions may ensue in these different situations. As proposed in the previous chapter, taken together, these conditions should be reflected as the varying abilities of institutional entrepreneurs to enable change. The second dimension, addressed the structural properties of the field, viewed through the number of organizations and diversity of actors attached to an emergent technological field. These properties influence the similarity versus diversity of technology-specific logics and innovation logics present among actors engaged around an emergent technological field, and the challenges for gaining a shared frame around this field. The third dimension considered the basis of institutional entrepreneurship and the legitimacy and ability of these actors to support and enable emergence of a technological field. The fourth dimension considered in the case selection, concerned the stage of emergence of institutional carriers of the field. The distinct properties of institutional carriers of technological fields in relation to the general properties of organizational fields are that technological fields are more critically dependent on each of the four carriers. With emergent technological fields, existing technology field structures are contested in various ways depending on the stage of emergence the new field at the addressed point of time. The stage of emergence of institutional carriers is only defined at a general level, separating between; (1) an initial stage; (2) an early emergent stage; and (3) an emergent stage. A more thorough analysis of different stages is carried out in the case study. The final dimension considered the source of institutional contradictions regarding both technology-specific and field level innovation logics. Although each emergent field imposes alternative technological archetypes in relation to the prevalent technological field, the cases differed in terms of how the new technological field imposed radically more efficient technologies versus substantially value-increasing technologies. The other dimension, related to differences of institutional contradictions in field level innovation logics, distinguishes between shifts from unconnected to coordinated innovation logics including coordination through a sectoral system of innovation logics. In one of the cases a shift from product and process-centered innovation logics to a science-driven innovation logic took place. These varying changes in innovation logics influence the challenges and degree of institutional contradictions that emerge.

Through a pre-screening process, a group of nine possible technological fields and related national technology programs were identified. This group was carefully evaluated according to the four predetermined dimensions. Four technological fields and related national technology programs that each provided the necessary distinct polar properties were finally chosen for the empirical case analysis (see Figure 3-1). The case analysis thereby came to include the following technological fields: the modular steel construction technology field, the functional foods technology field, the electronic publishing and printing field, and the well-being technology field.

The first case focuses on the modular steel construction field and the steel construction industry. The study specifically focuses on the Finnsteel technology program that started in 1996 and ended in 1999. The program focused on developing modularized steel construction systems and products and to shorten the construction time and costs compared to conventional methods. The second case focuses on functional foods and Finnish food industry. Two consecutive functional foods technology programs were implemented between 1997 and 2000 and from 2001 to 2005. The focus during the first program was on process innovations and research on the health impacts of different bacteria and natural ingredients. During the subsequent program the focus shifted towards innovation in functional foods. The third case examines well-being technologies in the health sector, and covers three programs. The Digital Media in Health Care technology program started in 1996 and ended in 1999. The following program, iWell-technology program lasted from 2000 to 2004. A third program, FinnWell followed in 2004 and ended in 2009. The fourth case focuses on the electronic publishing and printing technology field, and a program that included collaboration between two industries, the paper and graphic arts industry. The Electronic Publishing and Printing technology program ran from 1996 to1999 and focused on advancing the development and adoption of digital printing and promoting R&D activities on paper quality and business concept development for digital publishing. All the programs were funded and organized under Tekes, the National Technology Agency of Finland.

	Modular constructional steel	Functional foods technology field	Electronic publishing and printing	Well-being technology field
Market versus non-market conditions in industry	Market conditions prevalent in steel manufacturing and construction sector	From weak to strong market conditions	Market conditions prevalent in both paper industry and graphic arts industry	From non-market towards market conditions
Coherence of technological field frame and size of the emergent field	Coherent and small	Coherent and large	Diverse and small	Diverse and large
Basis of institutional entrepreneurship	Industry	Researchers	Industry and researchers	Government and researchers
Stage of emergence of institutional carriers of the field	Emergent stage	Early emergent stage	Initial stage	Early emergent stage
Origin of institutional contradictions in technology-specific logics	Alternative archetypes and radically more efficient technology	Alternative archetypes and substantially value increasing technology	Alternative archetypes and radically more efficient technology	Alternative archetypes and substantially value increasing technology
Origin of institutional contradictions in innovation logics	From unconnected to collaborative innovation logics.	From process and product centered to science driven innovation logics	From unconnected to collaborative innovation logics	From unconnected to sectoral system of innovation logics

Table 3-1Case selection matrix

3.4. Data collection

Three methods were used for collecting data: (1) semi-structured interviews; (2) archival data, including electronic, printed, and written material, and (3) secondary data, including previous studies and reports on the relevant technological fields. The semi-structured interviews, choice of informants, and gathering of archival data were guided by the framing of the empirical study previously outlined. Interviews were supplemented with archival data in order to capture and verify changes in awareness and institutional contradictions, and institutional entrepreneurship. This triangulation of the studied phenomena strengthens internal validity (Jick, 1977; Miles et al., 1994). The data collection focused on exposing the multi-level character of institutional entrepreneurship, awareness, and institutional contradictions. The data collection thus addressed individual-level awareness and institutional entrepreneurship, respective organizational-level properties and appearing institutional contradictions, community-level awareness, institutional entrepreneurship and institutional contradictions. The focus on multiple levels, and the attention to enabling and constraining mechanisms obtained from interviews and archival data, facilitates the reconstruction of the institutional fabric and socio-cognitive dynamics in effect at different stages of the emerging technological field.

It is important to attend to the multiple levels as *"change in institutionalized fields can only be understood as constant interactions between the various levels of analysis"* (Hinings et al., 2004:317). Equally, the socio-cognitive dynamics between the different levels are critical in order to study understanding of *"the relative roles and impacts of different levels at different points in the evolution of an institutional field"* (Hinings et al., 2004:317). In addition, the causal directions of socio-cognitive dynamics and emergence between different levels *"are not one-way but reciprocal"* (Hinings et al., 2004:317). By considering multiple levels, the empirical study design responds to the call by Lawrence et al. (2002) concerning the value of qualitative studies of organizational field emergence and the need to address localized dynamics of fields and the respective micro- and macro-level properties in these settings. Addressing the several levels of emergence in a field enhances feasibility for replicating the analysis (Lawrence et al., 2002). This increases the internal validity of the study. The data collection strategy aims to enrich the analysis and interpretation of interest and the encountered behavior of individuals, organizations, and the technological community. This should strengthen the explanatory power of the underlying socio-cognitive mechanisms that both enable and constrain the establishment and structuring of innovation activities in emerging technological fields. National technology programs are assumed to reveal the underlying institutional structures that the emerging fields encounter and the ability to configure these structures and reconstruct them in the context of emerging technological fields. As the program incentives were often followed by a subsequent program, these were also included in the analysis. This provides for better accounting of temporal inertia and the rather slow changes of institutions and strategies during disruptive field-level technological change.

In total 44 semi-structured interviews of individuals who were active in the four studied emerging technological fields were carried out during 2004-2005 (see Appendix B for a complete list and the Table 3-2 for a summary on each case). For consistency, the author conducted all interviews. Choice of individuals to interview was done following case study research and interview guidelines for improving the accuracy of retrospective reports

(Eisenhardt & Graebner, 2007; Huber & Power, 1985). Individuals knowledgeable about different aspects and representing different organizational fields, such as industry, research organizations, government agencies and ministries, and other organizations, were identified in initial discussions with those individuals actively engaged with the technological field at focus. Selecting *"numerous and highly knowledgeable informants who view the focal phenomena",* aimed at reducing 'convergent retrospective sense-making' (Eisenhardt et al., 2007:28). Both currently active individuals and individuals that had been or were now less involved were interviewed. Individuals with moderate levels of emotional involvement are important, as too high emotional involvement may lead to motivational or cognitive distortion and too low involvement may on the other hand *"result in casual deletion of information and the introduction of random errors"* (Huber et al., 1985:715). Actors with high emotional involvement are again valuable due to that they should be better in recalling factual data (Huber et al., 1985).

	Modular construction al steel	Functional foods	Electronic publishing and printing	Well-being technology field
Industry	5	4	3	1
Public research organization	3	3	4	2
Government agency and ministry	3	5	3	5
Other organizations	1	2	0	1
Involvement in field during mobilization and structuration phase (High/Medium)	H/M 7/3	H/M 11/3	H/M 8/2	H/M 7/2
Involvement in field in year 2005 (High/Medium/Low)	H/M/L 3/3/4	H/M/L 7/4/3	H/M/L 5/3/2	H/M/L 6/1/2

Table 3-2 Cohort of interviewees for the empirical study

To probe motives for cooperation with the interviewer, the strategies outlined by Huber and Power (1985) to remove disincentives for responding was applied. Interviewees were therefore presented measures, ensuring anonymity and confidentiality, and when not possible to provide anonymity, the option to review the manuscript before publishing was offered. Also the time needed for the interview was clearly stated to provide a non-hurried atmosphere. The semi-structured interviews were carefully organized to direct thinking and bring actors back into the contextual situation (Appendix A). To gain rich and exact information from interviews, follow-up probes suggested by Huber and Power such as *"Could you explain that to me?"* and *"So you mean"* were used. These have been found to increase accuracy of answers (Suchman, 1966). Then in snowballing technique was used, and individuals that would provide additional different viewpoints to the emerging technological field was identified at the end of each interview.

By using semi-structured interviews of active individuals, such as researchers, research managers, firm R&D managers and CEOs, government officials, university professors, and industrial association officials, all of whom may influence the direction and context of innovation activities, an emerging story line of technology field emergence and the conceived conceptions of the developments over time from 1994 to 2005 were validated. In this story line the focus was on identifying external and internal drivers and inhibitors of the developments and changes in the field. This was executed by focusing on assumptions about technological opportunities, enabling and inhibiting factors, and the nature of collaboration and possible roles of different actors in the field during different time periods. The interviews addressed meanings and the social and cognitive context actors had experienced, as well as the more factual developments of the field. By considering both of these themes in one interview the assumption was that the informant would better recall each phase and situation.

The structure of the interviews (see Appendix A for a list of themes covered and order of the questions) was set up to bring the interviewee back into the historical context and thereby elucidate on the novel technological field evolution through personal experience. Their occupational carriers were used as a tool to bridge individual and field-level emergence. This was accomplished by asking the interviewee to tell their career story in relation to the relevant technological field from their university studies up to present. They were then guided through the emerging and evolving field by focusing on different periods which could clearly be recognized by everyone, namely: (1) the time before program initiation activities, (2) the time of program preparation, (3) the program period, and (4) the time after the program had finished. In focusing on both external and internal drivers of development and change imposed from and on fields, organizations, communities and individuals, it was assumed that the most influential drivers would be exposed. Reliability was supported by letting 10-12 individuals in the field who held complementary perspectives describe their story of the evolution of the field.

Archival and secondary data from the period of 1990 to 2005 was collected for the case study. The rich set of archival data included meeting memos, personal communications, diaries, internal reports available from Tekes, and program planning documents and documents relating to the execution. Depending on the technological field at focus, there were different sources of secondary data such as, trade journal articles, reports on the field, professional association journals, books and compilations of the history of the field and the organizations, and topical newspaper and journal articles (see Table 3-3 for a summary of archival material used for the empirical study).

	Modular constructional steel	Functional foods	Electronic publishing and printing	Well-being technology field
Primary archival data				
Meeting memos, personal communications, and diaries	4*	7**	19	9
Internal reports by Tekes	5	10	10	8
Program planning and program execution material	15	20	61	32
Secondary archival data				
Reports and evaluations of technology field and program	6	13	12	3
Books and compilations on the history of the field and organization active	1	5	2	4
Articles in journals and internet related to technology field	6	19	7	0

* Including one personal diary on the planning phase of the program
** Including one personal diary referred to in detail during one interview

Table 3-3 Summary table of archival data used for the empirical study

A single story line and narrative was then generated based on the interview data, which was supplemented by archival data, program reports and material from trade journals. The analysis then proceeded by examining and comparing the story line and evolution of four technological communities in an emerging technological field with institutional entrepreneurship in these settings. This analysis was initially supplemented by grounded theory-driven coding of interviews using NVivo software for text analysis. While this analysis helped to further advance and direct theorization of the socio-cognitive dynamics and understanding the phenomena at hand, the coding itself did not converge and the use of coding in the case analysis is subsequently not reported.

3.5. Within and between case analysis

The case analysis starts by presenting the historical and institutional foundations that governed the interest, agency, and awareness of actors in the technological field at focus from the initial emergence of the field up to the initial activities of field-level mobilization. The four studied technological fields emerged in distinct ways. Therefore, the identified and distinguished phases of emergence before field-level mobilization are partly similar and partly different. As the field-level mobilization phase and field structuration phase are exposed to similar field-level enabling properties arising from national technology programs, they are both addressed in each case. Finally the state of the studied fields in 2005 is described in terms of apparent changes and emergent properties and the socio-cognitive dynamics in place at that time.

The case analysis is subsequently organized, such that the prevailing technological field that the novel field challenges or is emerging from is described in terms of its institutional carriers, their manifestations, and the dominant technology specific logics and innovation logics. Thereafter, the emergent technological field is analyzed by categorizing the development of the field in terms of the development, formation, and establishment of institutional carriers in the novel technological field. Specifically four institutional carriers are studied: (1) technological artifacts, (2) organizational and inter-organizational routines, (3) the relational system, and (4) developments in the symbolic system of standards and classifications. The developments of the institutional carriers give raise to institutional contradictions and institutional entrepreneurship. Distinct phases of technology field emergence are thereby identified. The idea is to distinguish phases that incorporate distinct socio-cognitive processes and emergent characteristics. The case study thus focuses on identifying distinct enabling and constraining mechanisms, specifically the awareness and institutional contradictions and the developments of institutional carriers in each phase of the emerging technological field. The focus in the case analysis is also on identifying transitions between the phases and how these are related to the development, materialization, and strengthening of each element of the institutional carriers.

The case analysis centers on dimensions highlighted by actors in interviews, in the documents produced during the studied period, and from secondary sources such as reports and analysis of the fields. In this respect this part of the analysis considers the social and cognitive processes taking place at the field level and the resulting interpretive conditions that direct an actor's sense-making, framing and awareness about technological opportunities and challenges. These interpretive conditions and processes are assumed to influence how actors frame their role and respective logics for action. Specifically, the technology field-level properties that were 'felt' and 'seen' by actors are attended to here. The socio-cognitive dynamics and emergent state of a technological field can thus be pictured as being constituted by an *awareness landscape*. It is this landscape and its shape that importantly directs subsequent emergent properties of a field.

After each individual case has been separately analyzed, a between case analysis is carried out in order to develop propositions on the emergence of technological fields at both macro- and micro-level, and the respective distinct phases and resultant socio-cognitive dynamics. This theory building phase draws on insights from recent work on stages in field emergence, with the intent to distinguish distinct properties and paths of technology field emergence from other types of institutional field emergence. The subsequent organization of the empirical analysis and following theory developing chapters is presented in Figure 3-1.

3.6. Internal and construct validity

Several measures were taken to strengthen the rigor of the case study. As these measures have been highlighted at several places in the previous sections, this section summarizes them in order to provide an overview. Four criteria are used for addressing the rigor of case analyses: internal validity, construct validity, external validity and reliability (Eisenhardt, 1989; Gibbert et al., 2008; Yin, 2003).

Internal validity was considered by drawing on the theoretical framing of technological fields as inter-institutional structures and the initial accounts from the literature review on emergence and socio-cognitive dynamics of novel technological fields that are outlined in chapter 2. Attending to multiple levels of the studied dynamics supported the building of an explanation and excluding rival explanations. Interviewing actors holding different positions and varying roles in the studied technological field provided important variety in interpretations and possible rival explanations that needed to be considered. Triangulation of the studied processes using multiple sources of data also strengthened internal validity.

Construct validity was addressed by using multiple sources of evidence (Yin, 2003), including semi-structured interviews, archival data, and secondary data such as reports and analyses of the studied fields. The case study is outlined as a narrative and aimed at establishing a chain of evidence (Yin, 2003) by addressing emergence and socio-cognitive dynamics and the micro- and macro-level links. Construct validity was also addressed by presenting the initial findings to key actors in each field, and by having the draft manuscript for each case narrative reviewed by one of the key informants who had a wide understanding of the emerging field.

External validity was considered by consistent use of institutional sociological theory and established concepts. The cross-case analysis provides a good basis for analytical generalizations on the emergence of technological fields, and more generally on the emergence of institutionalized fields and the mechanisms that enable and constrain institutional change. Reliability was addressed through transparency of the methods employed, case study protocols, and analysis frameworks (Yin, 2003). In the case analysis a substantial number of interview excerpts and excerpts from documents produced around the studied fields were used in order to strengthen reliability.

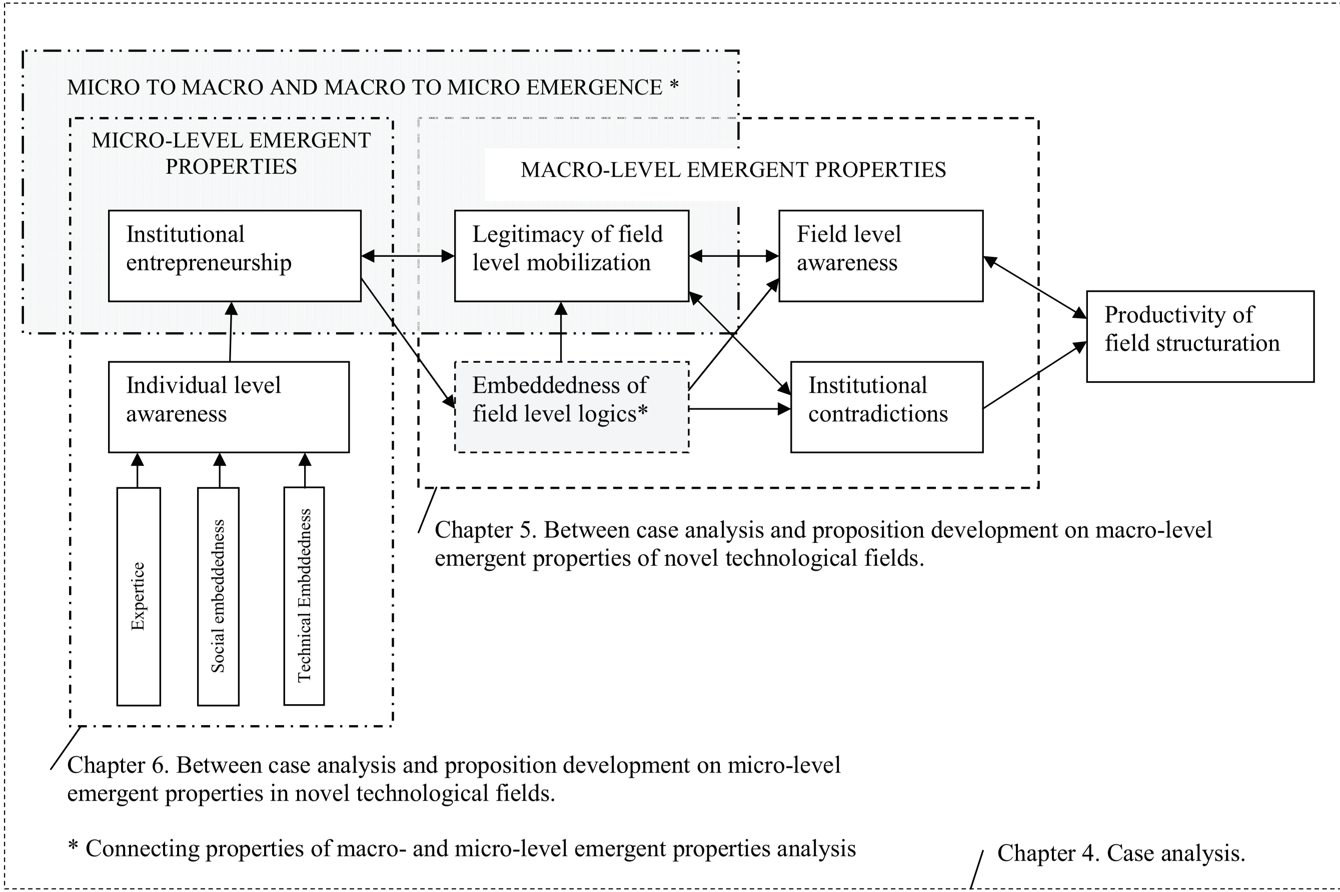


Figure 3-1 Organization of the empirical analysis

4. CASE ANALYSIS ON TECHNOLOGY FIELD EMERGENCE

In this chapter the case analysis of the emergence of four technological fields is presented following the outlined analysis strategy in section 3.5. The analysis starts by presenting and analyzing the institutional context the emerging field is with the development of the field going to challenge. Then the field mobilization and field level structuration phases are introduced and analyzed. Finally the stage of the emerging field in year 2005 is reviewed. A synthesis is then done on the emergence of the field, addressing the shift of technology-specific logics and innovation logics and development of institutional carriers of the field.

4.1. Emergence of the modular steel construction field

The emergence of the modular steel construction field is presented and analyzed in this section. The analysis separates four stages in the emergence of this field: (1) a cultivation and early innovation phase, (2) a local mobilization and structuration phase, (3) field mobilization, and (3) field structuration. These stages are distinct in terms of the social and cognitive dynamics and properties of emergence. In each phase, the analysis aims to untangle the central social mechanisms present that pattern awareness, institutional entrepreneurship and the institutional contradictions that arise. Thereafter, the state of emergence of the modular steel construction field in year 2005 is analyzed. Finally a case summary of the emergence of this field in Finland is carried out. This addresses the development of carriers in the field and the distinct properties of the shift in technology-specific logic and innovation logic.

4.1.1. Emergence of steel industry in Finland

Steel production as an industrial activity holds a long historical path in industrialized countries. In Finland the quarrying of iron ore started in 1540. Steel production emerged gradually in small iron works throughout Finland. After the Second World War Finland actively revived and developed its metal industry. This was mainly a response to the heavy war reparations that were demanded by the Soviet Union, which mostly included ships, machinery and other metal products (Ukkola, 2004). Until that time Finland relied mainly on scrap iron in iron production process, and most of the iron (2/3) came from import. By the end of Second World War most of the Finnish iron works had ceased their production. In 1960 Rautaruukki Oy was established by the government to supply the Finnish metal industry with steel (Ukkola, 2004). This domestic production period changed the scenery and the market for steel products in Finland (Hämäläinen, 2003). Rautaruukki’s main target was to capture the Finnish steel market that had formerly been dominated by imported products. It is from the establishment of Rautaruukki that the roots of the emergence of modular steel construction field in Finland can be traced. Specifically, the formation of Rautaruukki and the role it developed during 1960s and 1970s patterned and paced subsequent phases of emergence of modular steel construction.

The value chain of constructional steel evolved to include mining activities, manufacturing of steel and bulk products, steel structure fabrication, designers as architects and engineers for detailing, and construction companies. Until the late 1980s this interaction relied extensively on handcraft and tacit knowledge both in the planning and manufacture of steel constructs. Manufacturing of steel construction modules were extensively project based and very time consuming, and followed what several of the interviewees called an 'on spot' logic. The construction work progressed stepwise. Competition for the supply of building materials usually took place when certain materials or parts were needed. This often resulted in delays in constructional work when ordered materials were not delivered on time. No total optimization of building materials and constructional work was therefore achieved. The on-spot logic did not allow for the optimization of the construction work as one integrated project. This is a typical project work culture where practices may be reorganized each time in a slightly different way. Rather, micro-level optimizations and sub-optimal solutions had become the dominant practice. As a consequence the construction industry shared practices, routines, and problem-solving strategies following an 'on-spot' field logic for organizing work with the constructional steel industry.

4.1.2. Cultivation and early innovation phase in constructional steel

Parallel with the emergence of larger scale steel manufacturing industry in Finland, the establishment of three new technical universities in Finland took place[10]. Students entering civil engineering education in the country grew rapidly during the 1960s and 1970s, and stabilized at a level of 200-250 students entrants yearly. In addition, courses and dedicated university laboratories in steel construction were established in the 1960s and 1970s[11]. VTT, the Technical

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[10] Until 1959 only Helsinki University of Technology had provided the highest engineering education for construction engineers in Finland. In 1959 Oulu University was established and started to provide construction engineering education. In 1965 Tampere Technical University was established as a subsidiary of Helsinki University of Technology. Lappeenranta Technical University (LTU) was established in 1969.

[11] A course in steel construction planning at Lappeenranta Technical University was established by Professor Erkki Niemi under the education program of mechanical engineering. It was through coursework material that students together with the teacher produced material that laid the ground for steel construction practices in Finland. In 1976 the Laboratory of Steel-Construction (today Fatigue and Strength) at Lappeenranta Technical University was established. The first director became a newly examined student of the first steel construction course at LTU.

Research Centre of Finland established in 1943, had, from inception, applied industrial research in three areas related to modular steel construction, including construction technology, metallurgy, and bridge technology. These activities had, by the mid 1970s, substantially grown to include one (out of three) department in construction and civil engineering with 400 people (Michelsen, 1993).

In 1971 the Finnish Constructional Steelworks Association (FCSA) was formed to promote and develop the use of steel and other metals in the constructions industry (Terästiedote, 2001). Rautaruukki was the initiator and the 'host' of the association (in terms of resources and location). Until 1978 the activities were small scale. In 1978 and during the following years FCSA established technical, standards, and education committees. Together these forums and their related activities initiated educational and training for planning, manufacturing, use of steel in buildings, and the erection of steel constructions. Subsequently, during the 1980s the community of Finnish steel construction experts grew. Although universities provided the fundaments for both construction engineering and material engineering such as steel, the FCSA came to focus on updating and educating individuals and organizations in steel constructional work. With increased expertise and organized committee activities, the FCSA became a respected and legitimate actor for providing input and statements to legislators and regulators regarding the use of steel in construction and constructional work. In 1989 the FCSA office was moved from Rautaruukki's office. This was partly to distance the connection with Rautaruukki and their interests and to appear as a more neutral and credible actor, thereby enhancing what Suchman (1995) calls structural legitimacy of the organization. One aspect of the relocation was the option to move to a position adjacent to the Concrete Association of Finland. The apparent synergies from being situated next to this association provided additional support to this move.

The growth and developments of the discipline of construction engineering educated and cultivated an increasing pool of engineers with common categories and schemas for constructional steel. The interviews carried out for this study and the survey data on active individuals show that many of those who participated in the creation and development phases of education and research in construction engineering and steel construction, as teaching and research personnel, had by latter half of 1980s advanced in their career to influential positions in organizations within the field. In this respect the symbolic system had spread and established itself during the 1970s and 1980s through both established collaborative organizational structures, and through several task forces as an institutional carrier of constructional steel. The Finnish steel industry is peculiar in that the major steel fabricator Rautaruukki produces square hollow section beams (tubes) and hot rolled plates, but does not fabricate hot rolled profiles. For this reason welding developed extensively in Finnish steel constructional work in comparison to other countries where massive profiles are rolled.

Innovative steel profile manufacturers had established since 1960 in the wake of Rautaruukki's growth; for example, Teräselementti Oy. Mäkelä Metals Oy, PPTH Oy, Verho-Metals Oy, and Rannila Steel Oy. The utilization of steel on a larger scale in constructional work started in the early 1970s with industrial facilities applications, and this was picked up in office constructions and housing. In Finland the dairy company Valio built several production facilities in the early 1970s, which further boosted the development of steel construction architecture (Piironen & Saarni, 1998). The usual materials used in office constructions and housing were concrete and wood. With emerging competition between different materials in constructional work, especially between steel and concrete, but also wood, the arguments for the value of different material solutions in constructional work became increasingly bold and visible. A good example is the Finnish Constructional Steelworks Association's incentive in 1980 to start awarding an annual steel construction prize in recognition of high quality steel constructional work which was aimed at providing publicity and recognition to the use of steel (Vuokila & Turunen, 2006). It is typical of special-purpose organizations in an industry to organize contests in order to draw attention and enhance best practice (Holmstrom & Tirole, 1989). Certification contests are valuable in legitimizing organizations (Rao, 1994:32) and *"reduce the ambiguity caused by the lack of standards and the absence of complete knowledge"*.

Although concrete and steel competed as a material in construction, the organizations and professions that planned and erected constructions had, in addition to the steel industry, interests in developing mutual synergies. Engineering firms were particularly open and embraced steel, whereas construction firms that had invested in cement manufacturing and plants had fewer motives for actively increasing their use of steel.

4.1.3. Early mobilization and structuration phase

Strategic shifts in steel industry

In 1982 Mikko Kivimäki became CEO of Rautaruukki Oy[12]. Until that time the strategy of the company had been to produce and sell steel at the highest possible price the construction sector being one of several customers. During Kivimäki's era the company began upgrading and establishing value added products. This new strategy included internationalization activities, a

[12] Mikko Kivimäki was known as a listener who delegated responses and had strong analytical skills and preferences (Ukkola, 2004).

focus on productivity, strong customer service, and a focus on core markets (Ukkola, 2004). Budgeting and strategic planning became an annual process and five year planning was introduced. In 1987 Rautaruukki was reorganized from a line organization to a multi-divisional structure with business units and industry groups, including a construction division (Ukkola, 2004). While Rautaruukki was such a dominant actor in the domestic market at that time that all efforts to promote and advance the use of steel products became a strategy target. As one manager from the company described:

> We calculated that if somebody builds something of steel, then 80% of this is revenue growth for the firm (director at Rautaruukki)

Only Rautaruukki had, at this point, formally organized research and development (R&D) activities integrated within their product divisions (Rautaruukki, 1993). Other firms in the domain, such as engineering firms, software developers, and mechanical workshops mainly organized applied research and development activities as projects that were implemented in addition to normal business activities by the unit. At Rautaruukki, the Steel-construction Promotion and Advice Unit (TEN) was set up in the late 1980s. The idea behind this unit was to promote the use of steel in constructional work in Finland and to support customers and interest groups in the use of steel.

Several strategic acquisitions took place around 1990. Rautaruukki bought three manufacturers of profiled sheet, Verho-Metalli Oy, Mäkelä Metals Oy and Rannila Steel Oy. They also bought a 20% share in a major construction engineering group in Finland, YIT. With this acquisition the structural steel manufacturer Oy PPTH-Norden Ab, which was under YITs ownership at that time, was split so that YIT owned 60% and Rautaruukki 40%. At the same time Nordicon Oy, a steel element systems producer previously fully owned by Rautaruukki, was reverse split so that YIT held 40% and Rautaruukki 60%. This indicates that the existing relational system, including the normative authority system and the regulative governance structures were shaped and developed during this period. The two carriers developed at this stage, would later support further advancements and productive development of the symbolic system and technological artifacts around modular constructional steel.

Increasing engagements in standardization

Activities at the national research institute VTT in constructional steel intensified and excelled in the mid and late 1980s through active engagement in standardization and educational work in constructional steel at both a national and international level, and with the establishment of a strategic-level partnership between VTT and Rautaruukki.

In 1986, during a sauna session after a steel construction seminar at the firm PTTH, the immanent potential of information technology was brought up as an issue that the sector should start to pay heed to by an engineering firm manger (Interview with a firm director). By the early 1980s many engineering firms in Finland had already started to use computer-assisted design. It was then considered that Finnish steel construction industry should be prepared for the emergent changes and it was necessary to build the technological capabilities related to information technology in steel-construction. On the basis of this discussion a project named "New rules for steel construction planning (TSP)" under the auspices of FSCA started to be formalized. The aim of the project was to focus on generating general definitions and de-facto standards for steel construction in Finland. This included a database of definitions for steel construction, the process of steel construction production in Finland, steel grades and products, components (materials), and details required for construction design and work (Interview with a firm director). These elements were needed to support preparedness for the information technology in steel construction. A department director at an engineering firm was asked by the FSCA to become the manager responsible for the project, which started in 1989. The TSP project had over 30 participants including steel manufacturers (Rautaruukki), metal works, engineering firms, distributors/retailers, VTT Construction mechanics, Tekes, and FSCA. No architects or software developers where invited (which was a conscious choice) at this time to ensure a production technical focus (Interview with a firm director). The project continued until 1991. During the same period that TSP had started to formalize, a Tekes initiated and a funded project had commenced, named the RATA 2000 project, which aimed at advancing planning, engineering and building processes. Together these projects paved the way for larger scale collaborative research and development in constructional steel.

In the latter half of 1980s Finland joined the European Steel Design Education Program[13], through which Finnish international engagement in the international steel construction community started to unfold and central steel construction organizations became familiar; for example, the Steel Construction Institute in United Kingdom, and the French Centre Technique Industriel de la Construction Metallique (CTICM) (Interview with a researcher at VTT).

[13] The European Steel Design Education Program (ESDEP). This program had started in 1988, financed by the steel industry in EU and EFTA countries, with the aim to gather and develop education material on best practice in steel construction that would be available on a European level. Through this collaborative project the Finnish actors first made contact with the Steel Construction Institute from U.K. and CTICM (Centre Technique Industriel de la Construction Métallique) in France. The project ended in 1995 and had by then produced a complete encyclopedia of steel in construction, containing 201 lectures, 2000 line diagrams, 1000 slides and 21 videos.

Another standardization project CIMsteel [14] (Computer Integrated Manufacture of Constructional Steelwork) initiated as a Eureka project in 1987 was joined by Finland through VTT, FSCA, and Rautaruukki. The CIMsteel project initiated the development of the CIMsteel Integration Standards CIS, which focused on developing product model based standards for exchanging information about structural steelwork. The first version of the CIS standard was published in 1995. At this stage CIM was more a pilot than a ready standard[15] (Reed, 2002). A handful of experts from Finland actively participated in international projects and standardization committees[16]. During the early 1990s, due to Eurocode standardization work and the emerging CEN pre-standard, a large amount of implementation preparation work took place at the national level. The Finnish Standards Association (SFS) standards implementation work for steel construction was chaired, on most occasions, by a senior researcher from VTT who had been working with steel-constructional dimensioning and detailing since the 1970s.

Strategic partnerships between research and industry

A strategic partnership between VTT and Rautaruukki, formalized in early 1990s, included yearly strategic-level meetings, where Rautaruukki provided VTT with information on their current and upcoming focus, and ideas for developing the technological fields relevant for Rautaruukki (Interview with a director at Rautaruukki). In addition, interactions with researchers intensified. As one interviewee described it:

> There were sauna evenings and we developed ideas about what new things should be researched and then the researchers considered the ideas and made own propositions for research projects (director at Rautaruukki)

This more long-term based collaboration was described by active researchers during interviews as constructive, encouraging and long term and was highly valued. Furthermore, those individuals from Rautaruukki who were responsible for the collaboration commented that it was

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[14] The objective of CIMsteel was to develop effectiveness in the European Construction Steelwork industry through harmonization of design codes and related specifications. It included the introduction of computer integrated manufacturing techniques for design, analysis, detailing, fabrication, erection, and management functions. Its goal was to develop the exchange of digital information between applications and the effective management of this information.

[15] The specification work continued during the latter 1990s and in 2000 an updated and version, the CIS/2 was published. The CIS/2 standard covers the three major planning phases: (1) structural analysis, (2) structural design, and (3) fabrication (Reed, 2002).

[16] At a European level, activity in international standardization work in Finland is, together with Luxemburg (due to the gigantic steel producer ArcelorMittal), by far the highest per capita representative and the other countries come far behind (Interview with a researcher).

rewarding. In steel constructional work this strategic partnership started increasingly focusing on thin sheet technology, including durability, steel construction techniques, and fire characteristics. A yearly market research, strategy analysis, and business intelligence analysis was conducted by VTT on the constructional steel markets. This collaboration between Rautaruukki and VTT resulted in several master's theses, licentiate works, and doctoral theses. In this way the knowledge domain came to align, through *mutually enforcing focusing and awareness*, which strategically supported Rautaruukki's shift from a main steel producer, through downwards migration in the value chain, to a provider of fabricated modular steel constructional elements.

Technological disruption

During the early 90s the planning of industrial constructions moved from computerized 2D-planning to 3D-planning. Architects had earlier started using 3D-planning and by the latter half of the 1980s 3D-modeling was already a dominant working tool that was employed by architects. Thus the use of 3D-modeling by some actors in the value chain created pressure for others to follow suit due to the integration requirements of working methods (the same coding scheme reduced translation requirements). Although this integration process had started, other opportunities also emerged pushing for new working methods, such as computer-automated fabrication of steel structures, and investments in these technologies escalated in the early 1990s. The integration of planning and manufacturing through product electronic data exchange was therefore becoming possible, formalized in CRC-steered manufacturing and 3D CAD.

4.1.4.Field mobilization

Rautaruukki initiated discussions and negotiations for a national technology program in constructional steel in 1993. Mobilizing of field-level collaboration was part of Rautaruukki's strategy to initiate the wider participation of actors in the development of constructional steel technologies. These activities were aimed at supporting the increased use of steel and to support the development with the strategic target to acquire expertise and downstream assets in the value chain.

Probing and matching of interests

Inside Rautaruukki this incentive was led by the technology and marketing director and the head of the Building Products Division, in close interaction with the director of the TEN-unit and an expert in frame construction and safety and fire-related issues. The incentive also had the full support of the CEO and vice CEO[17], with whom the technology and marketing director said he had a *"shared vision about the opportunities in constructional steel"*. At the time the technology and marketing director was also a board director of the Finnish Steel Constructional Association. In this regard the director held an influential position not only in terms of his organizational position and the influential role of the firm in the industry, but also through his previous experience within distinct organizational fields in the constructional steel technological field. He had previously worked in the funding agency Tekes as director for the construction department, and as director at the state research institute VTT. This provided him with broad legitimacy and what Emirbayer & Mische (1998) describe as agentic element of projectivity for temporal engagement. Projectivity thereby functions as a rationale for agentic action.

The director had started exploring possible industrial actors who had an interest and technological synergies with the emergent technology field. This type of mobilization resembles advocacy as a form of institutional work that includes *"mobilization of political and regulatory support through direct and deliberate techniques of social persuasion"* (Lawrence & Suddaby, 2006:221). Although the actor already holds legitimacy this advocacy is related more to the mobilization of interest and resources in emergent technological opportunities. For emerging opportunities in modular constructional steel it meant actors working with steel structures that could benefit from modularity. In this initial field-level mobilization phase the director contacted two large firms that used steel in larger volumes, Mäntyluoto Works Oy and Tampella Power Oy. Mäntyluoto Works were at the conceptual stage in developing Spar offshore drilling platforms for the Gulf of Mexico[18]. Tampella Power, an established supplier of soda recovery and power boilers and boiler buildings, was at that time tendering for a larger contract for the delivery of three turn-key soda recovery boilers to Indonesia. The initial discussions aimed at identifying common technology and engineering related challenges and possible common technology-related opportunity paths in constructional steel that could be explored and developed in collaboration. Specifically, the focus in this exploration of synergies was on the modularity and standardization of elements and interfaces, in order to advance productivity, cost efficiencies, and quality in constructional steel work. These initial rather informal discussions also included elements of persuasion for engaging in a transition from the existing technological structures towards a novel infrastructure. To this extent, current institutional carriers in the predominant technological field were challenged by theorizing and *"elaborating chains of cause and effect"* (Greenwood et al., 2002).

[17] CEO Mikko Kivimäki and Vice CEO Lauri Mannerkoski.
[18] Mäntyluoto Works delivered the first in the world Spar platform in 1996.

Visioning

The initial probing was followed by the first meeting, and broader discussion about a collaborative national technology program, in the winter of 1994[19]. The director of the FCSA association made the formal invitations[20]. A group of around 10 individuals participated in the meeting. This group came to be referred to as "The Invention Group". This name reflected the group's task to brainstorm and elaborate on how to create a new base for the Finnish steel-construction industry (Interview with a firm manager). In June 1994 the director of Rautarukki moved to VTT to a director position in the construction department. Interestingly, this change of position did not interrupt or slow down the preparation of the planned national technology program. On the contrary, the preparation continued uninterrupted. One individual described this type of move illustratively:

> The Finnish construction sector and the Finnish Steel construction as a part of this is such a small sector, that we know the half to dozen people that take part from so long time back, and so well that it does not make much difference if a couple of men change chairs.

Although these initial discussions in the spring of 1994 were presented to Tekes, Mäntyluoto Works soon dropped out from the preparatory works for a national technology program in constructional steel. Several reasons have been presented for this, including the lack of technological synergies and value from modularizing in very large steel constructions, the more urgent matter of building the already ordered platform, and the vested resources in welders and the financial support received from the state to continue to employ them.

The structuring and framing of the program was driven by the key individuals from Rautaruukki, Tampella Power, VTT, FCSA and Tekes. Three thematic workshops were held to explore technological synergies at the project level, and to provide insights into the emerging opportunities offered by new technologies such as information and communication technologies. The engagement of the four most central actors, and the engineering firms and mechanical works was fairly easy. However, the participation and engagement of construction firms in technology development was more problematic. As one interviewee put it:

> The construction firm's product development normally takes place in the reclamation phase … hard to get the firms participating… Necessary as welding is one problem where failure takes place, wrong material order to wrong place and painting of metal surfaces in autumn.

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[19] The meeting was held in the town of Tampere at the facilities of engineering firm A-Insinöörit.

[20] FCSA provided a more neutral platform for this collaboration, although most of the actors knew about the close connections between Rautaruukki and the association. *"FSCA had an important role in the initiation, as a neutral actor which can gather the fiercest competitors to elaborate on common things"* (Interview with a firm manager).

These comments indicate that innovation and technology development in itself was at a low level on the agenda of the construction firms and the ideas about its value were not evident or convincing in the discussions. Also, it indicates that a shift in technology specific logic would be necessary in order to gain acceptance and a larger scale use of steel in constructions. To this extent, institutional contradictions were already present in these discussions indicating the upcoming challenges. These conditions influenced how different actors were either accepting or refuting engagement in this emerging technological field.

4.1.5.Field structuration phase

Although Tekes preliminary accepted the program in the late autumn of 1994, the agency had demands in terms of clarifying program vision and goals, an information technology strategy for the program, and opportunities for interaction between projects. Finally the agency also required Rautaruukki, Tampella Power, and the FSCA to have a technology strategy before the program was to start. This requirement was later extended to all participating firms. A program manager was recruited and the steering group set up in December 1994 following the positive indications by Tekes. The steering group included key individuals from Rautaruukki, Tampella Power, FSCA, Tekes, and the newly appointed program manager. The nomination of a senior researcher at VTT Construction to the position of program manager was based on the wide confidence and trust he had as an expert in constructional steel, especially through his active engagement in international and national standardization work in constructional steel since the latter half of 1980s. In summary, the field mobilization stage was critically driven by institutional work of advocacy (Lawrence et al., 2006) and considerations for legitimacy of field mobilization activities around the emergent technological field. These elements continued to be actively addressed during the field structuration stage.

The Finnsteel technology program started officially in the autumn of 1995 with the focus on developing modularized steel construction systems and products, and to shorten construction time and costs compared to conventional methods. The target was to reduce construction time by a half and reduce costs by 25%. This seemed to be an easy target because until then no one had really *"thought of construction times"* (Interview with a firm manager). Through these developments, the target of the program was to improve the international competitiveness of Finnish steel construction industry and to increase the markets for constructional steel (Tekes, 2000a). Although some projects had already had an early start in late 1994 and the first half of 1995 a call to all relevant universities and to VTT was sent out in the autumn of 1995 to gather and collect initial ideas for collaborative research and development projects. These proposals were analyzed and organized by the program manager and were then proposed to the board who were required to decide which should be financed and which should be grouped together. A first formal call for proposal was subsequently arranged. The program ran from 1995 to 1999. The budget of the program was estimated at 10 MEUR of which Tekes had committed to fund 4.5 MEUR; the rest expected to be financed by industry. The program targeted (1) the development of buildings, (2) joining technologies in steel sheet construction, (3) the development of new floor and wall structures, (4) the development of industrial buildings, (5) the development of design aids and tools, and (6) the strategic development of steel construction business. In total 58 projects, both research and industry-driven, were initiated during the program.

The program board evaluated the strategy and initiation of new projects and decisions about continuation or discontinuation of projects yearly. This procedure was sensitive to the emerging understanding and changing circumstances. The project managers of each project carried out a midterm self-evaluation of the program in August 1997 . The goals of the program were then revised, partly in reaction to recommendations from a wider technology field strategy project, partly in response to the midterm evaluation, and partly as a reaction to the failure to penetrate the East German repair construction market[21] - an initial point of focus. The domestic market had, at the same time, started to revitalize. The market focus of firms therefore shifted to the construction markets in the Nordic countries and the Baltic States, and subsequent development projects also reflected this during the second half of the program.

Field-level education and legitimacy of symbolic system

In order to change ideas and perceptions about steel in construction work and to get a constructor to try steel instead of concrete or wood required a lot of work and resources; as one manager at Rautaruukki described it:

> The biggest challenge was to get someone to try out something, because when they then tried they realized that steel was an excellent material in constructional work…to get them to test was kind of a breakthrough….I remember when discussing with construction firms and when I said that they would get the steel for free or even get some money they still doubted (director at Rautaruukki)

In response to these difficulties Rautaruukki decided to take on one construction project themselves in the town of Raahe in Finland:

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[21] The failure to succeed in the East German market was explained as a result of protectionism, lacking business relations, and understanding about local construction culture. Thus Finnish firms were unable to compete in the market.

> And then there was an empty lot…at that time a three story building was done in 11 months by a construction firms mainly by using concrete elements. The price at the time was 4500 FIM/m2. We did the house with our modular steel structures, and e.g. pre fabricated bathrooms, and using the Steel Building System project management software in 5½ months and the costs 3500FIM/m2. We then showed this to construction firms and contractors. Although we were competitors now…but we only wanted to show them… you make the construction work and we provide you with the modules we said…the contractors kept us as competitors as they own the concrete element factories…and we withdraw from these activities and kept the focus to providing the materials (director at Rautaruukki)

This example illustrates cultural-cognitive inertia in respect to the challenged identities related to the relational system and the symbolic value of the technological artifact (here concrete and steel) of the predominant technological field. The construction sector relates to existing field logics of steel as a bulk material and the value chain of the construction industry, which thereby attributes the identity and the role of bulk material producers in the construction sector. The response of the construction companies described in the excerpt is also in part due to the sunk costs in concrete element factories and the developed routines and practices of using concrete.

During the program, a seminar that presented the ongoing activities and perspectives emerging from program activities and provided a venue for social interaction was held once a year. These yearly seminars functioned as awareness raising events, which targeted the whole steel construction community.

From the start of the program, the Finnish Steel Construction Association increasingly engaged in legitimatizing and educating actors in the symbolic system of standards, classifications, and regulation, and in exposing technological artifacts of this emerging technology to the field and more widely to the market and society. An information letter 'Steelinformation' (FI: Terästiedote) was established, with 6-9 volumes a year from 1997 onwards, and a trade journal 'Steel Constructions' (FI: Teräsrakenne) was established in 1998 with four volumes annually. As part of assuring quality, in 1997 FCSA started providing certificates[22] for steel constructional work at the national level. These five year certificates became necessary for carrying out detailing in constructional steel work. This shows how the association provided important inputs for legitimizing and institutionalizing the carriers of the symbolic system of the emerging field.

Products, technologies, technical know-how, and planning support tools were developed during the program. Work within the Finnsteel program resulted in a total of 163 publications, including books, articles and reports. Most of these materials were sent by the FCSA to

[22] FCSA undertook both the evaluation and certification.

approximately 500 organizations around the world. In this regard the diffusion of the symbolic system and technological artifacts was increasingly directed towards international arenas.

International advocacy

Finland joined the European Union (EU) in 1995. With this, Finland also joined the European Coal and Steel Community (ECSC). Finnish industry thus started to pay a "production tax" to a common pool of R&D, organized through the Research Fund for Coal and Steel, which redistributed the funds to collaborative EU-level projects. The program manager was given the additional task to engage Finnish actors in European-level projects and initiate international projects that were in the interest of the Finnish steel construction industry, and aligned with the broader goals of the Finnsteel program. Four ECSC projects started by 1997 were Finnish initiatives (Tekes, 1997). Recognition of know-how and expertise residing within the Finnish steel construction community gradually emerged in the international steel community through high-level task force nominations and attainment of coordinator positions in several international development projects.

Framing and structuring of the relational system

The FSCA association, particularly through its activities since the more active phase after mid 1980s, provided fertile ground for the emergence of valuable social capital within the community of civil engineers. As the program started in 1995 the developed relational system and governance structure of organizing activities and projects was reflected in the intensified work in developing the technological field. As the director from Rautaruukki described:

> There emerged this spirit, which is an important thing…and there was clearly this atmosphere and spirit of doing and getting things done

But the idea of bundling resources and contributions and to collaborate with competitors was, in the initial phase of the program, rather strongly rejected. As the program manager described the challenge:

> I was broadly speaking shot when I proposed that 10 engineering firms would collaborate and that each would do their parts (a piece of software) and then the others would comment on it and in the end each would get the 9 others software programs for free…but a couple of engineering firms thought this idea was good … but then after three months all the 10 firms decided that the idea was wise … and we did this collaborative project and it has continued under a subsequent program also (program manager of Finnsteel)

This shift from rejection to acceptance indicates the value of the function of the program manager in this situation, and the role of pushing for the taking up of new forms of organizing innovation. It also illustrates how introducing new logics of innovation requires not only momentary but continuous advocacy.

A major strategy was initiated in 1995 for developing a sector-level strategy and to contribute to strategic choices and he formulation of new collaborative research and development projects. This project was led by the former director at Rautaruukki, now director at VTT for their construction department. The project included focused interviews with 35 CEOs and key people in firms in the sector, a survey of experts in constructional steel in the world, three workshops[23], and a final two day seminar held in the autumn of 1996 with the participation of key individuals in the sector. The final seminar focused on outlining the Finnish constructional steel sector's main targets for competitiveness, produce central development proposals, and to mutually decide the actors responsible for these projects. The project resulted in a report that outlined strategic directions for the sector.

Widening field structuration

Preparations for a consecutive program had already started in 1998. When Finnnsteel ended in 1999, research and development collaboration in constructional steel continued within the NICESteel development program from 2000 to 2004. The NICESteel program did not gain the formal status as a national technology program, even though Tekes funded individual projects. This meant there was no funding for coordination and the overall percentage of funding was lower than in the previous program. The focus of this development program was to intensify collaboration with contractors, architects, and construction firms. But it was difficult to find the same enthusiasm and a lack of legitimacy from Tekes was felt in the community. As one of the interviewees put it:

> Finnsteel was kind of an intellectual investment, and many key people had 'stuck their necks out' (FI: pistää itsensä likoon) and 6 years we had invested and then this consecutive program was introduced and therefore it is obvious that this new program do not move ahead with same enthusiasm (firm manager)

This suggests that engaging continuously in field level change activities exhausts the individuals and organizations involved and reduces motivation and interest in field structuration activities.

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[23] The workshops were thematically organized with the following themes: (1) possibilities of material and fabrication technologies, (2) possibilities of electronics and automation, and (3) possibilities of information and communication technologies. The seminars had session chairs and task groups, where they discussed ideas about how to develop the sector from each specific technological perspective.

4.1.6.Modular steel construction field in 2005

In 2005, after the NICESteel program, a research and development committee was formalized within FCSA to secure continuity for the collaborative research and development work. It was given the task to outline strategic directions for the sector and to make proposals to the FCSA board. In this respect the coordinated activities of research and development work were pushed towards institutionalized forms, partly due to the seemingly successful operation of the previous two programs and the general idea of field-level coordination and collaborative research and development work. At the same time, the FCSA had grown to include 72 member firms and 33 professional institution members; this covered nearly all the actors in constructional steel in Finland. Furthermore, awareness of the use of steel had increased. As one director from Rautaruukki described this field-level awareness:

> All actors in construction industry now know that steel can be used both as main material and together with other materials (firm manager)

The market share of steel in constructional work (residential and office, industrial plant) in Finland, grew from 5% in 1985 to 14% in 1995 and to 40% in 2003. With the increasing production of constructional steel, export had grown from around 90 MEUR to 2000 MEUR in 2004 (Elf, 2005). Similar developments can be seen from increases in Rautaruukki's turnover, which grew from 1280 MEUR in 1994 to 3654 MEUR in 2004. Rautaruukki's profits in 1994 were 111 MEUR and peaked in 2005 at 618 MEUR. Although this growth was partly related to acquisitions in both Finland and internationally, the shift from a bulk producer to a higher end product manufacturer had advanced rapidly. The turnover of constructional steel work business at Rautaruuki was 16.7 MEUR in 1991 and in 2005 it had grown to 550 MEUR. Other firms that participated actively in the program were also successful with their business. A Finnish software firm Tekla embedded the developed SteelBase platform into their X-Steel software[24] used for the design and detailing of steel structures. This software program reached 10 000 licensees in November 2006. The Finnish steel construction sector had, with the emergence and developments of the modular steel construction field, become a forerunner in product information transfer development through product data models such as Tekla Structures and the developed modular steel construction elements. An example of this success was the winning of the tender by Rautarukki in 2004 to deliver 12 000 tonnes of load-bearing steel structures for the main building roof and 22 main struts and more than 10 kilometers of welded secondary beams

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[24] The X-steel software integrates well with the fabrication process, as all of the information is stored in one solid 3D product model.

for the new Heathrow Terminal 5 project. In addition Tekla Structure was chosen as the program to design and manage the construction process of the terminal.

By 2005 Finnish experts and organizations had functioned as coordinators in over 20 international constructional steel field development projects. In 2004 the former program manager at VTT became centrally engaged in the writing of a strategic roadmap up to 2030 for the constructional steel field for the European Commission. This was part of a larger exercise by the Commission for the whole steel industry in Europe. In 2003 the American Steel Association acknowledged CIS/2 as the most applicable for use in the U.S. market. This indicates that the intensive research and development work during the Finnsteel program had come to shape an active and influential role for Finnish experts and organizations in the international arena.

4.1.7. A synthesis on emergence of modular steel construction field

In this chapter a synthesis is carried out on the specific stages of emergence in modular steel construction field. The synthesis draws together findings about the dynamics and paths in technology field emergence, specifically focusing on socio-cognitive micro- and macro-level properties. A synthesis on stages and development of institutional carriers and the properties of the shift in technology-specific logic and innovation logic is presented. Thereafter, the transition between the predominant technological field and the emergent field is conceptualized. This synthesis provides the basic contextual background, informed by the awareness and institutional entrepreneurship analysis, that together provide the data for the between case analysis and the development of propositions about emergence of technological fields.

Phases of emergence and developments of institutional carriers

The case analysis distinguishes four phases of emergence of modular constructional steel: (1) a cultivation and innovation phase, (2) an early mobilization and structuration phase, (3) a field-level mobilization phase, and (4) a field structuration phase.

With the establishment of education and research in the 1960s that later came to function as the bases for the emergence of the modularized steel construction field,, a cultivation and innovation phase of emergence had set in. In this phase developments of the symbolic system gradually intensified. Actors were increasingly engaged in learning, developing, and cultivating the classification and category structure of constructional steel. In this regard, the rules of the technological field were established, and the key elements of a boundary structure was formalized and gradually institutionalized. This was driven by the active enactment of the emergent symbolic system. Entrepreneurial and initial innovative activities in the ways of using constructional steel also appeared in this phase. A group of architects started using steel as a central material, first in industrial facilities and later in public buildings and in housing. Several mechanical works were established that started developing and manufacturing roof sheet profiles and steel profiles.

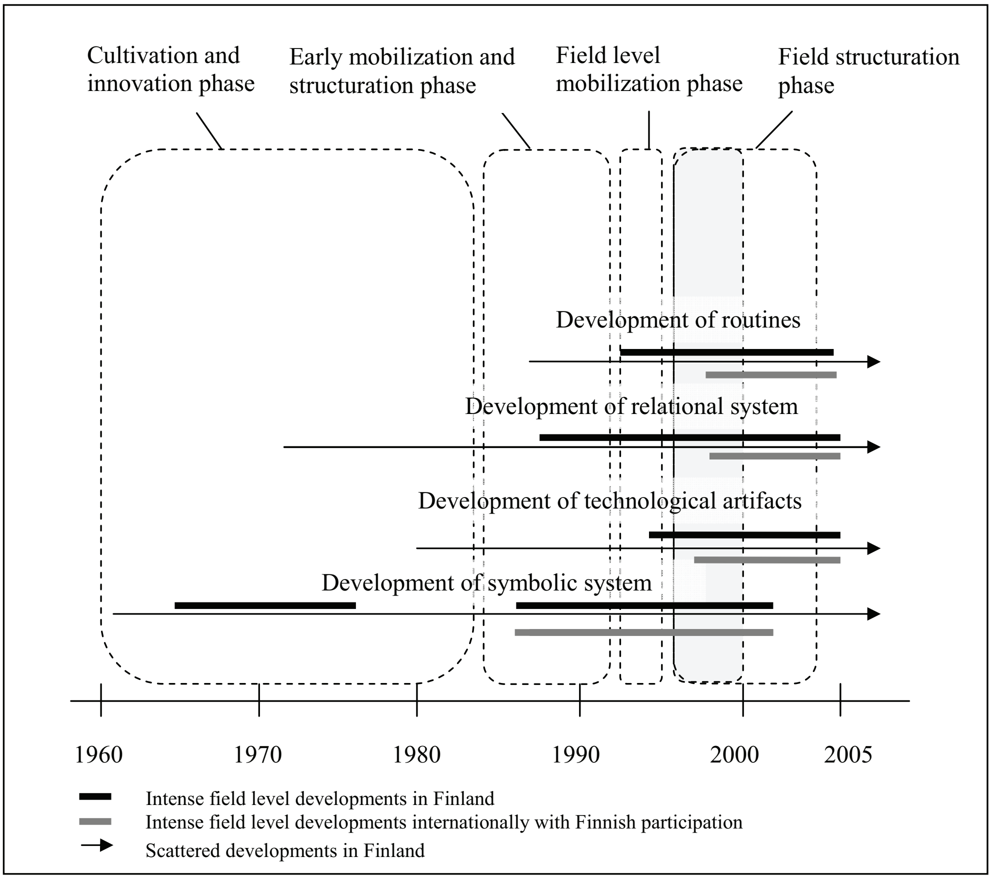

Figure 4-1Stages of development of institutional carriers of constructional steel technology field

With the strategy reorientation of Rautaruukki in 1986 and increasing activities of the Finnish Steel Construction Association, the emergence of the field moved to an early mobilization and structuration phase. This phase shifted the focus from the development of the conceptual structure of knowledge and human capital to a phase of active mobilizing of local actors and of early structuration. The phase centrally advanced developments of the relational and symbolic system and aligned the establishment of organizational and inter-organizational routines in the emergent field. With the increasing engagement of Finnish experts in international standardization work of constructional steel, a second stage in the development of the symbolic system was set in motion in this phase. These developments included the standardization of categories and typifications and the establishment of rules with regard to modular constructional steel work and artifacts. This engagement in international standardization work was partly in response to Finland's foreseen membership in EU by the industry but also emerged through developed expertise that, by now, was diffused both at Universities, within firms, VTT, and Rautaruukki, by the processes of the cultivation phase. In this phase actors were engaged through mobilization within organizations and among those actors that the organization was collaborating with. This phase was driven by established and strengthening social capital and the engagement of local actors in developing and structuring towards the emerging field.

In 1993 with the initial mobilizing by Rautaruukki and the technology and marketing director the emergence of the field began a new phase with distinct dynamics. This phase was dominated by field-level probing including advocacy, matching of interest, and visioning. Although this phase was rather short, it held important implications for patterning and directing subsequent developments of organizational and inter-organizational routines within the field. The legitimacy of institutional entrepreneurial activities was hardly contested in this phase. Actors' engagement and attachment seemed to depend centrally on interpretation, awareness, and significance the probing and visioning provided. Central to this were the developments and alignments of the organizational and inter-orgainzational routines that were already underway and the relational structure with respect to the emergent technological field. But not all of the actors and stakeholders who were engaged were equally motivated to embrace the new technology. At this phase institutional contradictions started to emerge, partly in the form of rejections to attachment to the emerging field, and partly as the challenge of attracting actors, such as construction firms to the visioning activities. Importantly, this phase also seemed to influence the direction and patterning of the subsequent phase of field-level structuration.

With the initial acceptance of the Finnsteel program in late 1994, the field moved into a field-level structuration phase. At this phase, activities for developing technological artifacts increased and the technology become increasingly visible and perceptible. As the program became formalized and launched calls for proposed projects, activities emerged that attended to developments of each element of the institutional carriers of the field. During the program, and continuing during the Nice Steel program, the field was intensively structured. Inter-organizational routines and the relational system particularly developed during this phase. A central social mechanism in this phase was the intense and frequent interaction between individuals and organizations in the field.

Shifting logics of technology field and contradictions

The shift from traditional constructional steel as a supportive material to an integral part of constructions faced several contradictions. The predominant technology specific logics included intense craftsmanship, and steel was mainly used as a supportive material. Interaction and communication between firms within the construction value chain was, by character, a one-way process during this era. The shift in technology specific logic included a move to use steel in larger scale and the material becoming more visible in constructions. This challenged the existing normative cultural-cognitive models of constructional work and the rationales for using specific materials. With the field-level structuration phase, and the simultaneous boom of the information and communications industry and rapid growth period in constructional works in Finland, steel became increasingly to be associated with modern technology and growth. This facilitated the isomorphic mechanisms of mimicry (DiMaggio et al., 1983) to gain strength and drive a rather rapid institutionalization of steel as a more central material in constructional work in Finland.

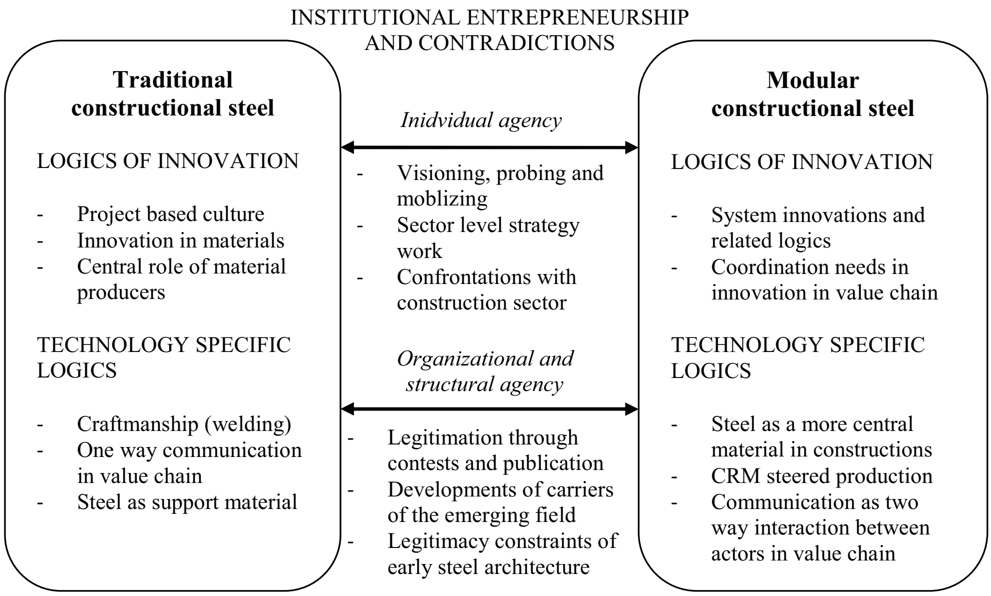

Figure 4-2 Institutional entrepreneurship and contradictions in the transition from traditional to modular constructional steel

Another central change in field-level logics was the shift from a project-based culture to a coordinated and collaborative system-level innovation culture. Although developments in steel as a material in constructional work had mainly focused on developing the bulk material quality and the productivity of the steel manufacturing process, the emergent stage required active and coordinated interfaces between the different actors in the constructional work value chain. This required system-level innovation activities and inter-organizational collaboration that often included several competitors. Despite these challenges and the changes in innovation logics, the actors who were engaged in the field were rapidly able to embrace this emergent new form. This appears to have partly been enabled by strong leadership and the powerful position Rautaruukki held in the industry. At the same time several strategic and legitimating maneuvers had taken place that facilitated this shift, including for example, sector-level strategy development work and active and frequent mobilizing and advocacy.

4.2. Emergence of Functional Foods Technology Field

The emergence of functional foods technology field is presented and analyzed in this section of the chapter. First, an overview of the emergence of food technology field in Finland is presented. The case analysis then separates four phases in the emergence of the functional foods technology field: (1) cultivation and early innovation phase, (2) early mobilizing and second innovation phase, (3) field mobilization, and (3) field structuration. These phases are distinct in terms of the socio-cognitive dynamics and properties of emergence. In each phase, the analysis aims to untangle the central social mechanisms present that patterns awareness, institutional entrepreneurship and the resultant institutional contradictions. Thereafter, the stage of emergence of the functional foods technology field in year 2005 is analyzed. Finally a case summary of the emergence of the field in Finland is carried out. This addresses the development of carriers of the field and the distinct properties of the shift in technology-specific logic and innovation logic.

4.2.1. Emergence of food technology field in Finland

The Finnish food industry has a long history. In order to establish an understanding of the institutional base of the field, including its organization and the base of the technology specific logic and innovation logic in the field, this section provides a short presentation of key events in the industry. Specifically the focus is on those elements and organizations that came to engage and be involved in the functional foods technology field.

Establishment of the Finnish food industry

At the end of 19th century, several collaborative structures for manufacturing in the food industry started to formalize. During the same period the agricultural research center MTT was founded in 1898 to conduct research into plant cultivation (Linkola, 1978). This was preceded by the foundation of the Finnish Association of Academic Agronomists in 1897, which aimed to support professional knowledge and to advance the interests of its members. The establishment of the Finnish food industry was partly affected by this early-formalized science-directed logic. In 1899 the bakers formed a union and the breweries formed their union in 1902. Soon after, in 1902 a law regarding cooperatives came in force and the butter export cooperative Valio was established. Valio quickly began to include other dairy products such as milk and cheese in its exports. With increasing numbers of members, Valio's focus gradually shifted to the domestic markets. In 1918 the meat cooperative Karjakeskuskunta and the sugar company Suomen Sokeri Oy were established. The flour mill Vehnä Ab, which later became Raisio, was established in 1939.

With the developments in the food industry, industrial research activities developed quickly in the biggest cooperatives and firms. A research laboratory was established in 1916 at Valio. In 1919 the newly examined doctor in organic chemistry Artturi I. Virtanen was hired and soon he became director of the Valio laboratory. The laboratory rapidly grew into a research unit with approximately 100 researchers. His research and the laboratory activities provided a central base for the development of high quality of Finnish milk, butter, and Emmental cheese. In 1931 Virtanen was appointed director of the Biochemical Research Institute at Helsinki; a post he held in addition to his position at Valio. In 1945 he was awarded the Nobel Prize in chemistry *"for his research and inventions in agricultural and nutrition chemistry, especially for his fodder preservation method"* (www.nobelprize.org). He was also active in university education and held a professorship at Helsinki University of Technology and Helsinki University. He remained at Valio as research director until 1970. After Virtanen's time as director, activities at the laboratory were challenging. As a former research director described it:

> Guys like Virtanen are only a few in the world, and in Finland they are only born about one every hundred year….it was impossible and it evoked criticism when trying to continue the in-depth research approach that Virtanen had managed but no results were seen at the economic side….thus the laboratory was split into two and a product development laboratory was formed along the research laboratory, but the practices remained still very much research oriented (a research director at Valio)

By 1978 the CEO of Valio had changed and a new research director had been recruited. The research laboratory that had been separated into two units after Virtanen's era were once again united, but at this time organized differently. A product development committee was set up where marketing, production and research directors, together with the CEO, came together to manage the product development process (interview with a research director at Valio).

Collaborative inter-organizational structures in research and industry-wide collaborative structures started to form during and after the Second World War. With the founding of Technical Research Center of Finland VTT, a food industry laboratory (Elintarviketeollisuuslaboratori) was established. In 1940 the Finnish Meat Research Institute was founded by meat cooperatives and their trading company to develop the meat industry from a scientific perspective (Aaltonen, 1997). The Finnish Food and Drink Industries Federation (FFDIF) was established in 1943 to represents and promote the interests of Finnish food and drink industries and to provide a forum for co-operation. Several industry joint research laboratories, located in the recently established Technical Research Center of Finland VTT, were also formed. One of the more successful laboratories was the brewery research laboratory (Panimolaboratorio) established in 1956 as an industry consortia by the brewing industry, which allocated funds received from beer sales taxation. During the 1960s and 1970s the laboratory capabilities and industrial research tasks at VTT subsequently grew with more test and piloting equipment, examples of which are a test brewer established in 1962 and a pilot fermentor built in the mid 1970s.

Professionalization of health and food expertise in Finland

Several expert organizations with a focus on the link between food and health formed in Finland after Second World War. The professional association, the Finnish Society of Food Science and Technology, was founded in 1946. Its main goal was to support the development of food sector development, to give expert statements to legislative bodies, and control in the food sector. The goal gradually evolved and broadened to include the promotion and development of *"scientific and technological research and education in the whole food chain, and also to improve cooperation and exchange of knowledge among the members of the society"* (www.etl.fi). In 1955 two central public health and patient association were established. That there were several local associations offering support to diabetics established after the Second World War gave impetus to uniting them to form The Finnish Diabetes Association. Its task gradually evolved to advocating policy, enhancing diabetes-related skills, and supporting people with diabetes. In the same time period the Finnish Heart Association was established in reaction to raising awareness of the escalating prevalence of cardiovascular diseases. Medical doctors held a central role in the establishment of these different 'social movements' that became formalized as associations that targeted widely distributed and typical illnesses in the population in Finland.

4.2.2.Cultivation and early innovation phase

Emergence of field-level cultivation structures

University education and research in foods expanded and developed extensively during the 1960s and 1970s (Savola, 1997). This expansion was partly supported by industry interests, partly through the established professional associations, and partly through funding from the United States Department of Agriculture (USDA). The USDA funding was part of the reparations that remained in Finland to support research into foods (interview with a research director from a firm). With this expansion phase, university education was formalized at Helsinki University and Helsinki University of Technology by the late 1970s through the establishment of curricula and degree programs in food science and engineering (Laakso & Leisola, 1997). During the 1970s and 1980s, information about research results and developments in food processing was *"amazingly"* freely exchanged between firms and research institutions in different countries (interview with a research director active in a firm during this phase).

Emergence of field-level coordinative structures for research

In 1971, the Finnish Food and Drink Industries' Federation established a research committee as a body to develop and direct research and education towards common areas of interest. The research committee included representatives from the 15 biggest food and beverage companies in Finland, accounting for the lion's share of R&D investments in foods. Subsequently, a research director position at the federation was established in 1972. A Food Research Foundation[25] (Elintarvikkeiden tutkimussäätiö) was also established at this time by FFDIF, which was managed by the board of the research committee of the federation.

The National Health Laboratory was founded in 1970 with 250 employees as a continuation and enlargement of the activities of the original National Serum Laboratory. The laboratory was later transformed into the enlarged National Public Health Institute with 400 employees. The Laboratory had set out several research projects that targeted public health-related concerns, one of which focused on the prevention of cardiovascular diseases in the North Karelia region. This project explored possible routes to combat elevated blood cholesterol and included recommendations for changing the contents and ingredient found in foodstuffs. This partly created the *"need for developing the Finnish nutrition industry"* (Ritvala & Granqvist, 2006:11).

Establishment of food regulation drafting bodies

The National Nutrition Council, initially chaired by A.I. Virtanen, was established in 1954 as a body under the Ministry of Agriculture and Forestry. It was established to follow and develop national nutrition incentives, instructions, regulations, and recommendations. Various interest groups from agriculture, the food industry, health care, education, consumer organizations, and research organizations were to be represented on the council (source National Institute for Health and Welfare webpage 2009). This council came to be dominated by professors and the interests of agriculture. Firm representatives were not allowed on this council; rather it was only industry representatives. This was because the focus of the council was to develop nutrition policy and not to twist the market in favor of some firms.

The Advisory Committee on Foodstuffs was established in 1988. This was partly in reaction to contestations in the field concerning the scientific evidence on the health-related effects and risks of margarine and dairy fat. The contestation originated from a dispute at Valio between the R&D manager and a professor who acted as board director on the Valio Science Committee

[25] The Food research foundation had 80 000-150 000 EURs annual to share.

concerning engaging in research on plant sterols[26] (Ritvala et al., 2006). This committee was, from its inception, driven by industry interests. The committee was organized under the Ministry of Trade and Industry to draft food legislation and handle matters relating to food control and the coordination of international cooperation in the food sector. The tasks of the committee included coordination of Finnish participation in the World Health Organization (WHO), the Food and Agriculture Organization (FAO) joint Codex Alimentarius standardization body, and to represent Finland at the EU. This suggests that the two bodies located in separate Ministries created a contested environment where different technology specific logics as well as different innovation logics were enacted. Although the National Nutrition council was centrally concerned with advancing nutrition-related values, the Advisory Committee on Foodstuffs focused on advancing market based principles and logics.

Early innovations

An early product that facilitated the emergence of the functional foods technology field in Finland in an important way was the Xylitol innovation. This nutritive sweetener was developed by the Finnish Sugar Inc. during the early 1970s. These developments were supported by increasing interest in public health policy in reducing the level of natural sugar in sweets during the mid 1970s (Markula, 2001). After initial rapid growth of production of Xylitol in 1976, the plant had to cut down production in 1977 due to conflicting findings about the health-related properties of Xylitol. After a standstill period, sales continued, but only outside US. Only in 1988, when Xylitol was finally approved by the FDA (the Food and Drug administration of United States), did the growth phase of the first functional food set off (von Hertzen, 2003). Xylitol thus functioned in many ways as an exemplar (Van den Belt et al., 1987) of the emerging technology specific logic around functional foods.

4.2.3. Early mobilizing and second innovation phase

Functional foods, also termed nutraceuticals, as a distinct category, and the subsequent framing of the technological field started to unravel in Japan in late 1980s. In Finland at the same time, preventive care was increasingly gaining attention, not only from extant research on the links between health and food, but also due to rising costs of health care and an increasingly diffusing awareness by consumers of the health-related aspects of foods (Markula, 2001).

[26] Later this professor proposed Raisio to engage in plant sterols, which they did.

Several legislative changes were introduced during the late 1980s, continuing until the early 21st century. In 1989 the decree on special products (349/1989) was put into force. The National Food Agency was established in 1990 to take on surveillance of Food legislation. The agency was charged with ensuring the safety of foods, promoting health and welfare of animals, and providing the required preconditions for plant and animal production as well as plant health (www.mmm.fi).

In 1988 the Finnish Food and Drink Industries Federation instigated a Food conference day; one in the spring of that year focused on industry-related matters, the autumn conference focused on research-related topics. At the same time the Finnish Food Product of The Year competition was established to encourage development and research in foods. The prize immediately gained good media attention and interest from firms (Hämäläinen, 2003). In 1990, the federation established the trade journal "Kehittyvä elintarvike" with five issues annually. In this respect several measures to further formalize the prevalent relational system (the social capital and legitimacy of the relational system) and the symbolic system (including regulation) in the food industry and research took place during the latter half of 1980s and early 1990s. Although these activities, in part, enabled the emergence of the functional foods technology field, they also partly directed the emergent structuration into a path that would impose several challenges in terms of the institutional contradictions that arose.

Second *innovation wave*

In 1989 Raisio, which since its establishment as a mill had successfully developed into a foodstuffs, animal feeds, and chemicals company, engaged in research on the possible use of sitostanol as a nutritional food supplement. This explorative work, initiated by a renowned professor at Helsinki University[27], resulted in the invention and patenting of sitostanol ester in 1991 (Ritvala et al., 2006). This invention sparked the developments of the first functional food product, Benecol margarine, which held cholesterol-lowering effects. The entrance of Benecol into the European and U.S. market in 1995 is considered the birth of the functional foods market in these regions (Mellentin, 2005). Although Xylitol had provided the initial direction and awareness about the opportunities in this emergent market, Benecol achieved enormous international publicity, reflected in the fact that it was responsible for a 10 times growth in the stock price of Raisio over a single year; this created legitimacy for the field.

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[27] This professor was the same person who had previously acted as Valio's Science Committee board director and had proposed to Valio that they engage in plant sterols; however, he failed in this endeavor.

Another invention that equally influenced the emergence of the functional foods fields, especially in Finland, was the Lactobacillus GG (LGG) probiotic bacteria. This bacterial strain was separated, identified, and patented in 1987 by two US professors. Valio bought the license in the same year. Early, highly costly and time consuming clinical research on the health-related aspects of probiotic LGG was mainly carried out in Finland and coordinated by Valio. But as international research groups requested to research the strain, overall research of LGG expanded. It subsequently became the most studied probiotic in the world with an extensive safety assessment record (Markula, 2001). Valio launched the Gefilus brand and the first products with a LGG ingredient included a yogurt and a fruit drink that were launched in 1990. Due to production problems and consumer dislike of the consistency the production and marketing was put on hold for a short period and then shifted to the production of sour milk that included the LGG bacteria. In 1996 Gefilus was re-launched. Although prohibited by law, Valio started aggressively to market the Gefilus products health-related effects that were reported from research and awareness about its products rapidly increased. However, at the same time the authorities approached Valio and subsequent marketing campaigns were required to leave out explicit healthy claims as these were strictly controlled by the authorities and existing laws (Markula, 2001). This example illustratively shows the institutional contradictions arising between the prevalent and the emergent technology specific logic and the related mismatch in the symbolic system, including existing regulations and classifications that did not support or embrace functional foods. At the same time, these institutional contradictions further enabled the need to articulate and legitimize the novel technological artifact and its symbolic value and the related symbolic system. As a result intense activities to claim and articulate the identity of functional foods emerged.

Framing of functional foods as a distinct technological field

The concept of functional foods and its translation to Finnish *"terveysvaikutteiset elintarvikkeet"*[28] appeared around Europe in about 1994 (interview with a professor). The definition and framing of the concept gradually settled, and by 1999 the following definition was widely recognized in the field:

> A food can be regarded as 'functional' if it is satisfactorily demonstrated to affect beneficially one or more target functions in the body, beyond adequate nutritional effects, in a way that is relevant to either an improved state of health and well-being and/or reduction of risk of disease. Functional foods must remain foods and they must demonstrate their effects in amounts that can normally be expected to be consumed in the diet: they are not pills or capsules, but part of a normal food pattern (Nutrition_Society, 1999).

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[28] Direct translation: *foodstuffs with health impact*.

Functional foods thus came to be positioned between food and pharmaceuticals in terms of its classification and how one should act towards its development, safety, and the use of this technology. Although health-related aspects of foods were not new, the scientific evidence with regards the specific elements of the food, such as probiotics, antioxidants, fibers, and bioactive peptides, and the systematic extraction of elements of ingredients was new (Schmidl & Labuza, 2000).

More traditional health-related effects of foods, such as nutrition and components of healthy diets, were already widely spread and institutionalized in Finnish society through the professionalization and established institutional carriers in the food technology field. Early mobilizing activities were therefore faced by resistance and apparent institutional contradictions triggered by the novel framing. As one researcher described the situation in early 1990s in Finland:

> I was one of the first to start talking about the health-related effects from foods and that they are important here in Finland….at a seminar at Pyhäjärvi institute we discussed this concept of functional foods ....and then following the Finnish Food and Drink Industries Federation research committee meeting, we discussed that this was a trend but several of those present were really skeptic and laughed and joked about target foods (FI: täsmä ruoka) and hotdogs and these kind of metaphors and they did not really believe in it at first.

Industry internationalization and consolidation

The Finnish foodstuff industry had since World War Two, as a response to strict market regulation, developed into a diverse sector with several subsectors (Ulvinen, 2006). In 1988 the revocation of the law regarding price control on foods was enacted. This change, emerging during the 1980s, had been pushed by a wider shift in economic policies in developed countries towards market capitalism and included deregulation of industries and an increasing belief within the government in market mechanisms and value of competition as a means to slow down increasing food prices (Hämäläinen, 2003). Subsequently, several cooperatives were dismantled, for example Tuottajain Lihakeskuskunta (TLK) was dismantled into two separate firms Atria and Helsingin Kauppiaat Oy (HK) in order to promote competition in the subsector. Driven by increased market forces, consolidation and rationalization occurred towards end of the 1980s and during the 1990s. During this period, there was also an initial proposal, put forward by a few Finnish visionary industrial actors, to consolidate the food industry on a Nordic level and establish for each segment one company, e.g. one sugar company, one mill, one dairy producer (interview with a firm CEO). This initiative became stranded early on due to opposition, especially from Norway. Internationalization in the food industry accelerated during the early 1990s in the beverage industry and the cookie and candy industry. Growth was primarily sought from investments in firms in the Baltic States and in the Nordic countries (Volk, Laaksonen, & Kallio, 2000).

Emergence of Nordic and EU level collaboration in research

With the role of research strengthening in the development of foods during the mid 1980s, research collaboration contract practices were also developed with the advent of new collaborative structures. Research in Finland then started to internationalize in the late 1980s, both in terms of focus and funding. Within the European Community science and technology program COST[29], a Food Technology project was started in 1988 in which Finnish food researchers for the first time participated on a larger scale and were funded through European collaborative programs. During the early 1990s VTT became increasingly active in participating and coordinating EU funded research projects within the EU framework programs. Increasingly, there were also activities towards influencing the scope of the framework programs from Finnish researchers. In the same year that Finland started participating in EU programs, the Nordic Industry Fund initiated a four year Nordic Biotechnology program (NO: Bioteknologisk samarbeidsprogram), and the following year the NordFood program commenced. Finnish industry and research participation was active in both programs. The NordFood program was followed by a consecutive program which ended in 2000[30].

Failed field-level mobilizing

In 1984 the national technology program committee[31] proposed 12 technology programs to be established in relevant industry areas. One of the 12 proposed programs was framed around the aseptic packaging of foods. Tekes, which was established in 1983, subsequently initiated the planning of this program. After two years of preparation, including negations with research institutes, universities, and firms the program proposal was buried. This failure to mobilize actors was, in part, due to existing competition and conflicts between university actors, reflecting contradictions in both technology specific logics and innovation logics; this was mainly between the research institute VTT, Helsinki University, and Helsinki University of Technology:

> It was nearly impossible to get the three department professors from these three research strongholds (VTT, Helsinki University, and Helsinki University of Technology) around the same

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[29] COST is acronym of European Cooperation in Science and Technology for coordinating nationally-funded research on a European level (COST web page).
[30] The NordFood 1 and NordFood 2 programs were organized by Nordisk Industrifond
[31] The Hassi committee was led by Gustav von Hertzen (at the time CEO of Finnish Sugar)

> table at the same time. This standstill situation were removed when generational shifts later took place (an expert at Tekes at the time)

The formation of collaborative projects and a collaborative program in the food technology field was therefore inhibited by the embeddedness of the relational system by a competition mode of research actors, and the institutionalized professional hierarchy that provided normative power to department professors who were fixed on unit-level research principles. At the same time there lacked the industrial commitment and interest for funding and inter-organizational collaboration to be treated equally. As one expert at Tekes at the time described it:

> We were too early perhaps…on the other hand this was a period when the food industry was still protected through agricultural economic subsides and control and competition was mainly domestic

Although the plans for the original food-packaging program were buried, a Eureka project was initiated by the firm Walki Paper to develop materials for aseptic packaging. Tekes also continued discussions regarding another potential collaborative program around the increasing research interest by the dairy, meat, and enzyme industry in milk fermentation. In 1988, a new initiative and field mobilization emerged for a food technology program. Preparation was this time carried out by the Finnish Foods and Drinking Industry Federation,[32] and a proposal to Tekes was subsequently presented. The plans received the go ahead from Tekes, and preparations for this program commenced. Valio was given the task to engage in negotiations with the field, and to outline a more detailed program proposal. These preparations failed to find common ground and true interest from the industry. This failure was partly explained by the legitimacy constraints of Valio, and their partial preparation. Also, the proposed innovation logics presented by Tekes contradicted the prevalent logics and the isomorphic rationales for non-collaborative research and development work.

> And negotiations for a collaborative program took place during a period then…but the timing seemed again a bit too early, while everybody wanted all what was proposed, nobody was willing to share and give to other actors (an expert at Tekes during the time)

In this regard the lack of legitimacy of mobilization and the newness and non-institutionalized logic of collaborative innovation practices critically influenced the lack of acceptance and field wide awareness of the emerging technological opportunities in the field. Subsequently, the plan to start a national technology program was put to rest a second time. In the early 1990s food industry sector specific research and development programs were initiated by VTT and the

[32] Initially this was an initiative taken by Sitra.

industry. Subsequent programs targeting the brewery industry and the mill and bakery industry[33] did take off.

From applied industrial research towards biotechnology

In the early 1990s VTT had started to scale down the test and analysis services that had been a central activity of their laboratory. This was partly due to increasing engagement in research projects and their technology development activities. With this shift, increasing demands for external funding emerged. External funding from Nordic collaborative programs, EU funding, and industry funding from abroad was then targeted (interview with a professor). In addition, increasing collaboration with other Finnish research units started to formalize. In the mid 1990s collaboration between Kuopio University and VTT commenced; the focus being on jointly exploring the health-promoting effects of fiber and plants. Professor Hannu Mykkänen at Kuopio University had been central in developing research and education on the health-promoting effects of fiber and plants.

Graduate Schools were introduced in Finland as a new form of research funding by The Academy of Finland in 1995. In the same year, the Applied Bioscience Graduate School (ABS) was established as a partnership between four universities and four research institutes. It focused on bioengineering, food, nutrition, and environment-related research. A central theme in the ABS graduate school was research in functional foods. The ABS graduate school thus became the setting that enabled the development and education and diffusion of cultural-cognitive institutional elements related to functional foods, such as evaluation routines, symbolic categories, schemata, and relational system related identity.

Although the professional and research-oriented advances in foods had started to develop, research and development investments by industry was on the average low. In 1993 Finnish industry invested around 50 MEUR in research and development, an average of 0.4% of production (Guillaume & Zegveld, 1995). This prevalent innovation logic, that had coexisted and recently been further formalized around the technology specific logic related to foods as products, was now challenged by functional foods and a focus on ingredients.

4.2.4. Field mobilization

During the early 1990s, up until Finland's membership in EU in 1995, there were divergent viewpoints on the necessity for succession incentives within the food industry and the industry

[33] The firms Fazer and Vaasan were main industry participants in the program.

federation. This dispute, and the uncertainty over how the industry would survive under the new arrangements, extensively impaired the collaboration between firms during the early mobilization phase. These conflicts resulted in the near break-up of the federation. With the approaching EU membership, and foreseen market changes, the industry increasingly agreed on the necessity to broaden the competitiveness of the industry and to engage in growth strategies, including market growth and the broadening of production.

Finland became member of European Union in 1995. Terms of membership included the removal of import tolls for foods and the opening of the Finnish food market to firms from all EU member countries. Equally, the European food market was opened to Finnish firms. This was a real challenge for the industry with changing market conditions. Until that time the food industry had been mainly driven by market pressures in the domestic market, which was sheltered by export barriers from international rivals. Competition, although existing, had thus been dominated by few actors, and frequently one firm had a near monopoly position in the product segment (e.g. dairy, brewery, sugar, meat, and corn). This suggests that the prevailing business logics were challenged and that the industry needed to respond to these foreseen changes.

For the period of transition the government set up a succession fund of 15 MEUR that was targeted at research and development for the sector. This was to be used during the following two years (1995-1996) and was part of a larger policy document published in 1994 on the support measures for the food industry that the Ministry of Trade and Industry and Tekes further developed into a five year (1995-1999) support scheme. The scheme included support for competitiveness-enhancing investments, the support for research and development work referred to above, and support for the internationalization of the industry (Tekes internal document). In addition, a five year plan for supporting small and medium size enterprises in the industry was outlined. This said, Finland's membership in EU had already been anticipated by several firms since the latter half of the 1980s. Firms had therefore already taken steps towards adapting and taking advantage of the foreseen change of market dynamics in this industry.

During the same period VTT was restructured into nine research institutions, and the VTT Biotechnology and Food Research Institute was established. VTT had an established practice of its own R&D programs that often ran parallel with Tekes programs. This was partly for the coordination of project activities and partly to function as a platform for industry R&D managers to enable awareness and field-level emergence. As a researcher at VTT explained:

> With VTT programs the aim was to advance synergies and value that people would contemplate together and that the entire knowledge base would be developed….and then as an external interface it has profiled and given a "face" to these activities at VTT and this is communicated quite widely

In 1994 VTT established an internal technology program for foods. During the following year larger strategy work was carried out by the industry federation, which sketched the main lines for a technology program. This initial program was detailed to target functional foods and new food processes. The rationale for these two areas addressed a shorter-term focus on increasing the productivity of the production of foodstuffs, and a longer-term focus on creating competitiveness in the industry, with products providing additional value for customers through functional foods. In 1996 the Functional Foods national technology program commenced.

4.2.5. Field structuration phase

Two stages are distinguished in the field structuration phase. In the first, the explorative field structuration stage, discovery-driven activities were dominant, while in the later structuration stage the focus was much more on developing business and products, and related relational structures and practices.

Explorative field structuration (1996-2000)

With Finland's EU membership, and the emergent exemplars of functional foods, interest for collaboration in research and technology development had increased, both at the research level and within industry:

> Yes everyone were engaged, everyone that was in the field in Finland and the idea was that Tekes, through the functional foods technology program, would enable the establishment of links and networks between research groups and the industry and to get links between bigger firms and the small and medium size firms in the industry (research director of a firm)

Research topics had already formed through an interactive process organized by Tekes in 1995, where researchers first presented their existing research and the potential opportunities for the food industry and then the industry presented their aspirations and interests. Finally actors were left to group themselves together in thematic areas.

> At this stage this collaboration between research and industry was new and they were far from each other… those things what the research groups presented and what the industry was able to imagine in terms of what things could be utilized and further developed in projects …we threw a lot of things 'on the table' and most of what the research groups presented they wanted to continue and it was a difficult situation for the industry with their own interest to direct research so that it would become commercialized in the end (research director at a large firm)

In subsequent programs, collaborative research projects were, from the start, set up to explore the health benefits from oats, rye, soya beans, wheat roughage, probiotic bacteria, plant sterols, phenol compounds from berries, herbs and plants, and the reduction of salt and fat. In addition, innovation and research in process-related technologies were initiated. The program innovation logic was more exploratory than focusing on exploiting existing knowledge:

> The program gave broad opportunities for many different things and the idea was to see what the program would contribute to, so there were not very detailed goals in this first program and there was this thinking that at some stage after doing this some things that perhaps would then be utilized would start to appear (research director at a firm)

Still, at the beginning, the industry was reserved about disclosing their intentions and their own knowledge and know-how. The initial start was also hampered by increasing uncertainty over the survival of research activities at larger firms:

> It looked as if Valio would stop the whole R&D activity….that long term development would end and only the product modification part would remain to save costs due to the changes in the market conditions….but then there was this shift one year later when they realized that with the basic products and only product modification and product development the firm will not survive and as the history and knowledge in basic research was so strong, this could have to be utilized in this new situation (research director at Valio)

This suggests that the largest industry actors converged to rely on the capabilities developed in research, while faced with challenges for matching these with the emergent technology-specific and innovation logic around functional foods.

Within the functional foods technology program, 113 research projects and 90 industry projects were financed. The program lasted from 1997 to 2000. The total budget for the project and program activities was 31 MEUR. Tekes share amounted to 20.8 MEUR. From its inception, the program attracted attention from both domestic and international public media:

> The program generated a lot of interest for example on TV, radio and in newspapers, and we gave numerous interviews in relation to the program and what functional foods was and also international newspapers were frequently in contact…and this encouraged us to further focus the program

These amplifications provided valuable support to legitimizing the symbolic value of functional foods and to facilitating identity with respect to the emergent relational system. With the progress of the program, collaboration between research and industry developed:

> In the beginning there was this distrustfulness and cautiousness …and as the research driven project then got financed and as you know each projects has a steering group with both research and industry representative and through these project meetings the collaboration got better and better and we learned to know them and speak the same language and perhaps the distrust started disappearing ….the other thing that affected this development was the contracts that Tekes required each project to use and this clarified the whole field

Several structural changes started to unravel during the program. In the same period as the mobilization of the functional foods technology field, the industry cluster model spread in Finland. This had been taken up by government and economists at research institutes as a central response to renewing and developing both existing and new industries. Eight cluster programs were finally launched in 1997, including a food cluster program. The coordination of the program was given to the Ministry of Agriculture and Forestry, and 2.5 MEUR was allocated for the period 1997 to 1999. A second structural change that took place during this phase was to university curricula, which increasingly had taken on a natural science and economics based foodstuff science approach. This change influenced a curricula and research shift of focus from animal medicine towards food hygiene science with an emphasis on technical sciences and public nutrition (Linko, 1997).

A third change that took place during the first program was the Novel Foods Regulation (EY 258/97) which came into force in 1997. This gave birth to a third body in food regulation in Finland, the Novel Foods committee, placed under the Ministry of Trade and Industry. Only with the establishment of this committee did VTT become actively involved in legislative work in the food sector. Although implementation and national coordination and representation towards EU bodies were allocated to the Ministry of Trade and Industry, the National Food Agency was given the role of overseeing the approval of novel foods[34]. This legislation was difficult to accommodate, especially for small and medium size firms, because it required extensive clinical proof which was costly and took a long time to demonstrate. It also proved difficult to obtain approval for new ingredients[35]. This regulation became a great challenge for the functional foods field. The legislation originated from that put in place for Genetically Modified Organisms, and required that these foods needed safety assessment before being placed in the EU market. To be approved as a novel food requires unanimous acceptance by member-state novel foods authorities, and if not received requires an evaluative process by the European Commission. Taken together, these difficulties and challenges around rules and laws and related categorizations and typifications to accommodate functional foods emerged from

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[34] The National Food Agency lies under the Ministry of Agriculture and Forestry.

[35] "Commission must take an authorisation decision with the assistance of the Standing Committee for Foodstuffs." (EY 258/97) "Under the assessment procedure, the competent body of the Member State which receives an application must make an initial assessment and determine whether or not an additional assessment is required. If neither the Commission nor the Member States raise an objection, and if no additional assessment is required, the Member State informs the applicant that he may place the product on the market. In other cases the Commission must take an authorisation decision with the assistance of the Standing Committee for Foodstuffs." (EY 258/97)

institutional contradictions when drawing on the symbolic system of food and medicine. By the end of 1990s some functional foods had started to sell well in the international market:

> It was in the late 1990s and there was a general concern that the investments in Xylitol would never pay back but suddenly it started to sell in Japan and Korea and now sell so well that the product has now been further developed (research director at a firm)

This gradual emergence of technological artifacts and the exposed value from these products brought increasing legitimacy to further develop the symbolic system to match the distinct properties of functional foods.

By 1999 the food industry federation had outlined a technology strategy for the sector. This included both a review of current changes in the markets and customer behavior, and the vision about developments of new technologies. Biotechnology and bio-science, material technology, and information technology were identified as the most important technologies for the Finnish food industry to consider. Based on this analysis, general competitive factors for the industry were outlined. This strategy process of the research committee of the federation and the resultant document provided avenues for further framing the subsequent program in 2000.

Development of business and products phase (2001-2005)

In 2001 the subsequent technology program 'Innovation in Foods' commenced, continuing until 2005. The program aimed to *"promote consumer-oriented product development and commercial applications of new food technologies"* (Tekes, 2005). Specific research areas targeted by the program included; gut health, plant-based substances promoting health, separation and encapsulation techniques, and commercialization process management. To this extent, this later program focused on taking stock of completed research, and facilitating the commercialization of findings and the knowledge developed from research within the previous program.

> Target-oriented approach was taken by Tekes with the second program in functional foods, and it was argued that applications should be found…and at this stage the public health dimension was raised and the program was named in Finnish 'foods and health' …and at this stage there was a wider round were doctors for example and representatives of medicine were invited and junctures between health and food were searched for…. to clarify the health-related aspects (research manager at a big firm)

The focus on application and commercialization of functional foods knowledge reflected a shift in innovation logics, from the previous focus on research and discovery, which was driven by Tekes. The demand for results from government spending on research and development was emphasized during the second program. These demands included an increasing interaction between organizations and the sharing and spread of knowledge. This logic seems to have become institutionalized in public research organizations through the first program:

> It was a real dramatic change process that lasted throughout the first Tekes program, so during this phase those involved were really concerned who they engaged with so that nothing of what they know could be revealed too much…but then there was this second program phase and at this stage there credit was given in the application stage to consortia type projects so that the more actors there were in the consortia the easier it was to get funding…and this was now understood by research institutes and that this is smart, sensible, to build larger consortia instead of creating these things alone, so it was this kind of cohesion impact. (researcher)

This shift was further supported by changes to the food law in 2001 in accordance with EU directive (2000/13/EC). The change of the food law in Finland (737/2001) permitted the use of claims of the illness reducing impact of food products and ingredients, but with the requirement to present information on reported health impacts and the impact of diets on health.

Formalization and developments of relational structures within the research domain unfolded during this second phase of structuration. The Functional Foods Forum, an independent special unit of the University of Turku was established in 2001 to bring together expertise in functional foods. The unit rapidly grew through several research and industry projects within the second program. In the same year, MTT Agrifood Research Finland was formed through a merger of the previous Agricultural Research Center (MTT) and the Agricultural Economics Research Institute (MTTL). This created an institute with a total research budget of 44.6 MEUR. With the establishment of the new research institute the policy target was to increasingly direct the institute towards both advancing research in foods and agriculture, but at the same time to increasingly invest in product development and commercialization of developed know-how held by the research institute. A change in respect of the funding of the institute had thereby taken form. Additionally, Kuopio University and VTT Biotechnology formalized collaboration by establishing a Food and Health Research Center (ETTK) at Kuopio University. This formalization was preceded by the increasing involvement of researchers from VTT in research and education at the university. In 2002 a professorship in functional foods was established at Helsinki University. These changes indicate a shift in innovation logics within research, towards collaborative structures and the proactive advance of the commercialization of know-how from research, and the fostering of leading edge research both in Finland and at the European level. These developments in research enabled the development and formalization of organizational and inter-organizational routines within these contexts in conjunction with the emergent technology-specific logic of functional foods.

4.2.6.Functional foods in 2005

The emerging field of functional foods increasingly gained traction with larger firms engaging in firm-level strategic shifts. Raisio sold its chemical division in 2004 and announced a focus on plant-based nutrition, functional foods, and food safety. At this time Benecol products were sold in 20 countries and Valio were reported to have sold licenses for the use of the LGG bacteria to 39 countries by 2005. These developments enabled the further legitimization of developed routines and of the temporary relational system that had been established with the two consecutive programs. Interestingly, participation of small and medium size enterprises, which during the first program amounted to 142 firms, had dropped to 67 during the subsequent program.

Since Finland's membership in EU the food industry had increased exports from 670 MEUR to 1032 MEUR in 2005. The biggest export countries in 2005 were Russia, Sweden, and Estonia. Several firms[36] had functional food products on the market and the estimated functional foods market in Finland in 2004 was 70-80 MEUR. The global market growth of functional foods was at this stage 6-10% per year, which in 2004 amounted to about 50 billion Euros. Despite this growth the emergence of the functional foods market had been slow and was still uncertain. Although firms such as Valio and Raisio, which had invested extensively in functional foods, hardly grew during the years between 1995 and 2005, firms in the meat industry had more than doubled their turnover during the previous 10 years. The largest firms in the sector had increasingly embraced functional foods through the ingredients added into foods that provided higher value for both customers and the producer. This said, no large scale specialization in the industry had developed. The legislation for novel foods in the EU was seen as a major bottleneck for the structuration of the field:

> Five years ago we applied for permission to add this ingredient in our products, for example in bakeries, in sweets, and also in basic foodstuff…. we have subtracted the application now so that it only would be used in a certain type of bread with certain type of grain…and the scientific committee have said that it is safe …but still it did not go through (research director at a firm)

> This novel foods legislation ….our large firms in the food industry are nearly afraid of that their food would have to go through this 'mill' and I must admit, when I'm a member myself of the committee that it's a really tough 'mill' and it functions in each country …and you have to get the acceptance from all countries…and it's a clear 'break' at the moment for this development (research director at a research institute)

[36] Raisio, Valio, Fazer Teriaka, Multibene, BioFerme, Juustomestarit Oy, Atria, Sinebrychoff, Alimetrics, and Omegol.

Several reasons for this bottleneck can be traced. Firstly, the emergence of functional foods had started challenging the pharmaceutical industry, and ingredients were conceived as something between drugs and food, which imposed substantial normative regulative needs on functional foods. Secondly, the big controversies relating to GMO food had raised cautiousness about biotechnology and food; the latter being central to functional foods. Thirdly, the threat of novel foods to traditional foods, and a lack of wide legitimacy especially at the European level, created skepticism and negative responses. Together these mechanisms contributed to the strong institutional contradictions that seemed to impede the structuring of the functional foods technology field.

The development and diffusion of cultural-cognitive elements and the symbolic system in the functional foods field excelled between 1995 and 2005. This diffusion was enabled through the numbers of ABS graduate school PhD graduates within the field. By 2005 of 122 graduated PhDs, 59 had jobs in university, 37 in research institutes, 20 individuals in industry, and 6 in public administration. To this extent, the symbolic system had come to spread through actors that were now embedded in distinct organizational fields attached to the functional foods field.

Further science-driven developments of the symbolic system, routines, and the relational system had occurred with increased participation in EU framework programs, and increasing project coordination by VTT and MTT. Inter-organizational collaboration had advanced and facilitated developments of the relational system and routines between researchers and industry actors.

> At the personal level, you learn about units and even transfer of knowledge about devices has happened, one can borrow a device which would previously, I'm not sure have been impossible but at least within projects it is much easier when we know they have the same project…and then expertise has widened from the previous phase, and when the atmosphere is much more open, where one does collaboration, we have subsequently observed how the organization in the field have gained increasing expertise, and this has also helped in gaining international relations (research director at a one research institute)

Also, novel ways of facilitating the spread of the symbolic system and of technological artifacts had started to emerge by 2005. VTT had agreed to consider the challenge by testing the leasing out of researchers to established firms in the field for a two year period. This arrangement was intended to facilitate development of organizational routines as well as inter-organizational routines between research and industry, and within respective arena.

By 2005 the field seemed to have gained increasing legitimacy. As one interviewee explained:

> The director at the National Public Health Institute did talk at the 'bread week' last year very positively about the functional foods field and there was also this *'eat bread by prescription from the doctor'* campaign that through an internal medicine doctor gained large publicity in the media…it has taken such a long time before these 'nutrition folks' have started to talk about these functional foods. It is only now that rye has becomes self-evident in their recommendations.

To this extent, the symbolic system and the materialized technological artifacts had gained wider legitimacy and these carriers of the functional foods field seem to have increasingly become institutionalized. In 2005 a Food and Nutrition Program was commenced by Sitra, the Finnish Innovation Fund. The program targeted about ten venture-capital investments of 15–20 MEUR in companies, and other sector-specific incentives.

4.2.7.A synthesis on emergence of functional foods technology field

In this section of the chapter a synthesis on the specific stages of emergence in functional foods technology field is carried out. The synthesis draws together findings about dynamics and paths in technology field emergence, specifically focusing on the socio-cognitive micro- and macro-level properties. A synthesis of the stages and development of institutional carriers is presented. Thereafter, the transition between the predominant technological field and the emergent field is conceptualized. This synthesis provides the basic contextual background, which, informed by the awareness and institutional entrepreneurship analysis, together provides the material for the between case analysis and the development of propositions about emergence of technological fields, and the role of awareness, institutional entrepreneurship, and institutional contradictions.

Phases of emergence and developments of institutional carriers

The case analysis distinguishes four phases in the emergence of functional foods technology field: (1) a cultivation and early innovation phase, (2) an early mobilization and second innovation phase, (3) a field mobilization phase, and (4) field structuration phase. In 1950s the National Nutrition Council was established in response to increasing awareness and understanding about the links between nutrition and health. This paved the way for further strengthening and widening university education in food sciences and food technologies during the 1960s and 1970s. This period laid the ground for a strengthened science-based education and science-driven innovation logic to further spread in the field. Research organizations, such as the National Health Laboratory, and collaborative research structures between industry and research, such as the Brewery laboratory and the research committee in the Food and Drinking Industry Federation, subsequently formed during the 1970. These organizations embraced the science-driven logic. This suggests that routines and relational system gradually strengthened and formalized between research and industry. In the mid 1970s the ‘first’ functional food innovation Xylitol, was launched to the market. With this innovation, the technological artifact of the emerging industry started to take shape and challenged the current conventions and standards around foods and the symbolic system that the food industry and research centrally relied upon.

During the 1980s the science driven logic in food technologies further strengthened with the establishment of an annual food research conference and trade journal in the field. This increased the legitimacy of the science-driven food technology-related symbolic system. It was also in the mid 1980s that the initial attempts at mobilizing a collaborative industrial research and technology development program in the field was carried out. Due to lack of industry interest and distrust among research groups between universities and research institutes, the mobilization failed. Instead, public research actors sought funding and collaboration opportunities through European and Nordic research programs in foods; this commenced in 1988. By the early 1990s two innovations in functional foods had been developed, the LGG probiotic bacteria, and the Benecol and sitostanol ester. These innovations sparked intensified developments in the functional foods field. Although LGG products already appear on the market in 1990, it was only with the market launch of Benecol and the prelaunch of LGG products that the emergence of field-level mobilization and structuration in functional foods in Finland was importantly shaped. These early innovations, which by then had entered the market, centrally manifested the technological artifacts as an institutional carrier of the emerging field.

With the first technological program in the functional foods field starting in 1997, development of organizational and inter-organizational routines begun. Routines in industry and research started to establish; these built on the previously established science-driven logics and the preexisting relational system between industry and research. Although industry thereby became increasingly involved in the emerging technological field, the relational system between firms and between industry and research was not challenged or persistently adapted to the emergent technology-specific logic. Only with the second technology program in functional foods, which commenced in 2001, did the focus shift to commercialization around functional foods. This shift in innovation logics was a response to increasing demand for results from the funding invested in research, and in part followed the predominant purpose of the funding agency Tekes. The role of this agency was that of the facilitator for the emergence of new technological fields, but withdrawing at a certain stage from actively directing further structuring of the field through program activities. This became challenging due the strongly held institutionalized practices, routines, and skills embedded within the science-driven logic and dominant product-centered business logic. Furthermore, it was only during the second technology program that the previous non-market organized industry started to respond with corporate strategic changes, adaptations, and reorganizations. The firm Raisio sold its chemical division in 2004 to centrally focus on the functional foods field, and at Valio there was increasing legitimacy and the resource commitments towards functional foods. By 2005 the functional food field was thus in a phase of structuration, whereby all the elements of institutional carriers of the technological field were developing concurrently.

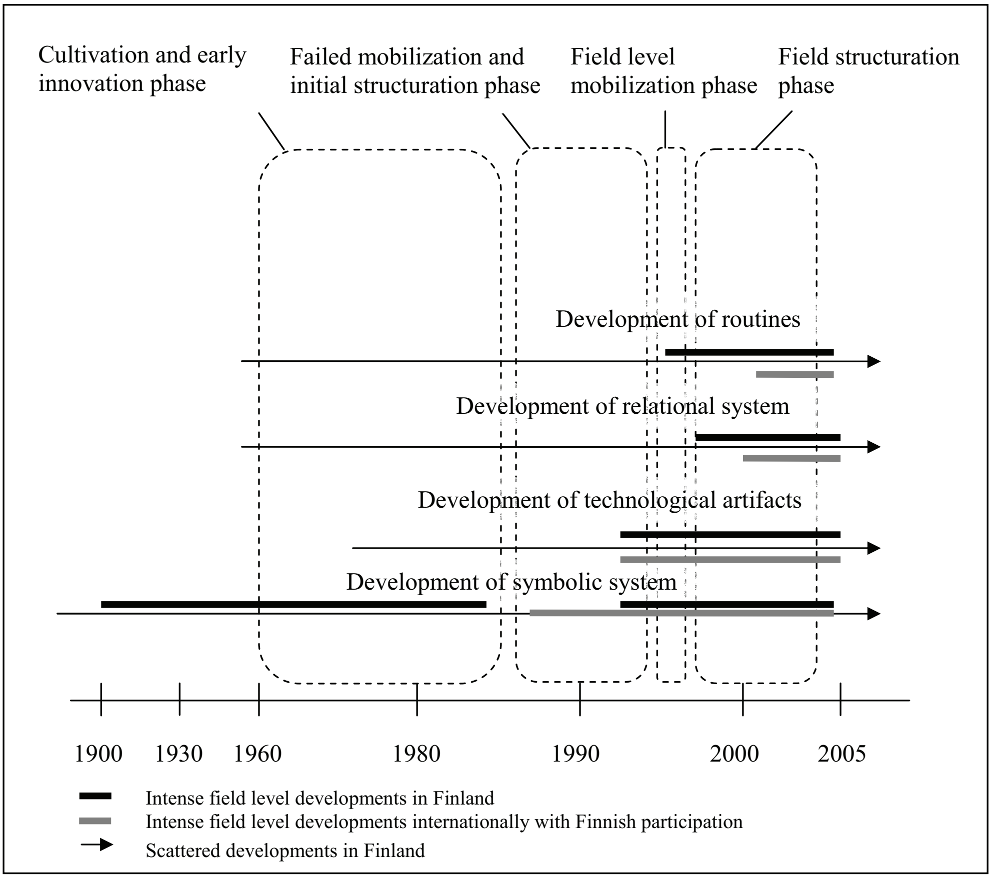

Figure 4-3 Stages of development of institutional carriers of functional foods technology field

Shifting logics of technology field and contradictions

The shift from the traditional food technology-specific logic and innovation logic to the functional foods field logic included several challenges. First, the technology-specific logic shifted the attention from food products to ingredients. This shift then imposed challenges with regard to changes in the value proposition and symbolic value of foods. Second, the emerging field of functional foods challenged existing business logics that relied largely on a domestic food production value chain, with one that included international food manufacturers as a central customer group in addition to current retailers and end customers. Third, the shift in innovation logics from short-term product development centered logic to science-driven innovation logics imposed several challenges with regard to the intensified links between research and industry. In order to take stock of the opportunities in functional foods, the path that emerged centrally determined the resultant challenges and institutional contradictions. The science-driven logic that emerged during the 1990s was, in part, a response to the institutional contradictions encountered by the emergent field and the active research community. Although the research community provided momentum and institutional entrepreneurship, at the same time, they challenged the prevalent relational system and organizational routines. Due to legitimacy constraints within the existing field level logic, the changes imposed took time to gain traction. The shift from a national to international researcher community collaboration logic especially challenged the prevalent planned and controlled activities with the imposition of more explorative and emergent driven processes. Only with the wide diffusion of the symbolic structure, achieved through education, research, and visibility of technological artifacts, did the field gain the legitimacy necessary to engage actors in productive field structuration. This paved the way for active firm involvement, which started developing the relational system of the emerging functional foods technology field. While legislative developments and new laws at the national level supported this shift, the struggle to legitimize functional foods in the EU impeded the process for a more all-encompassing industry-wide level shift.

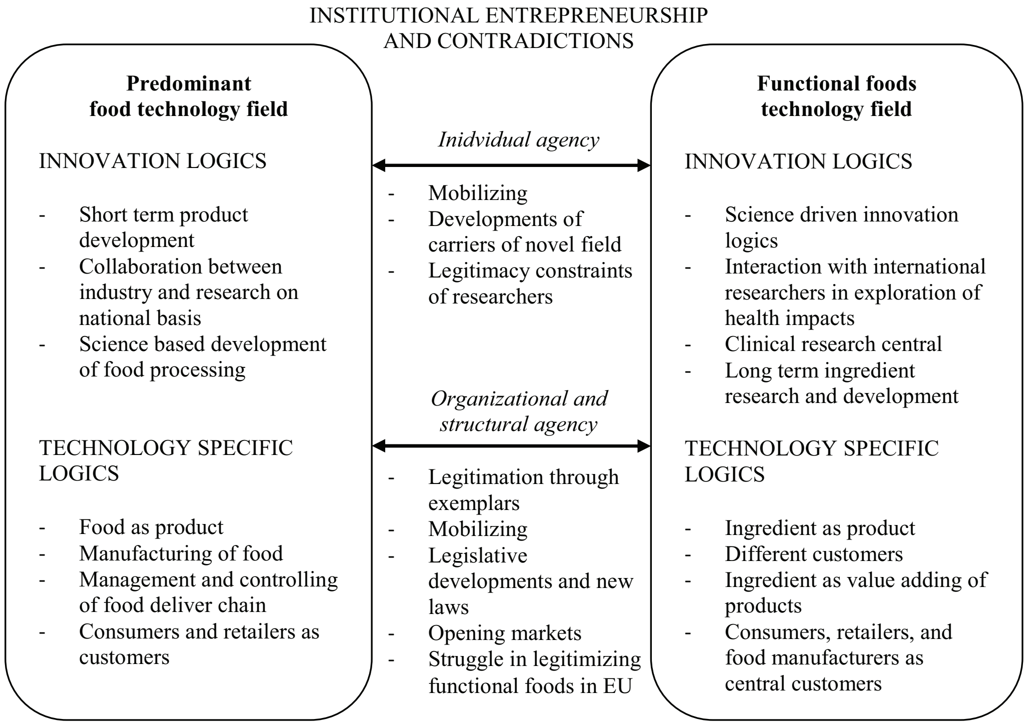

Figure 4-4 Institutional entrepreneurship and contradictions in the transition from food technology to functional foods

4.3. Emergence of electronic publishing and printing technology field

The emergence of electronic publishing and printing technology field is presented and analyzed in this section of the chapter. To account for the observed socio-cognitive dynamics and the resultant institutional contradictions, the post-war developments in the established industry - the paper and graphic arts industry, and their technology - are first described. This is followed by the analysis of the emergence of the new technological field - the electronic publishing and printing field – where four stages of emergence were found: (1) the cultivation and early innovation phase, (2) the early structuration and mobilization phase, (3) field mobilization, and (4) field structuration. These stages are distinct in terms of the social and cognitive dynamics and properties of emergence. In each phase, the analysis aims to untangle the central social mechanisms that are present which pattern awareness, institutional entrepreneurship and the resultant institutional contradictions. Thereafter, the stage of emergence of the electronic publishing and printing technology field in year 2005 is analyzed. Finally, a summary of the emergence of the field in Finland is carried out, addressing the development of the carriers of the field and the distinct properties of the shift in technology-specific logic and innovation logic.

4.3.1. Post-war developments of the paper and graphic arts industry and technology fields

During the post-war period in the 1950s and 1960s the pulp and paper industry had progressively developed with increasing exports to Europe. This phase was supported by the active economic policies of the state. The industry continued growing during the 1970s and the 1980s, especially in paper exports and the volume of high quality papers. This period was dominated by value and capacity increasing investments in the industry (Sajasalo, 2006). Increasingly, rationalization became a central issue on the agenda of firm. These developments materialized in several mergers during the latter half of 1980s and the early 1990s. In 1986 Metsä-Serla Oy was established through a merger between Metsäliiton Teollisuus Oy (industrial branch of Metsäliitto co-operative) and G.A. Serlachius Oy. In 1991 a union between the firms Rauma Repola and Yhtyneet Paperitehtaat to form Repola, which in 1995 was consolidated with the firm Kymmene to form UPM-Kymmene.

Despite the successful growth and internationalizations of the Finnish paper industry, the industry produced relatively few patented innovations compared to other industries in Finland. Research in the industry was organized in both dedicated R&D units within the firms and at the joint industry research center KCL (Oy Keskuslaboratorio Ab), which functioned as a limited company owned by the most central paper firms in the industry Metsäliitto Yhtymä, Myllykoski Oyj, Enso Oy, and UPM-Kymmene Oyj. The industry owned research institute KCL was established in 1916 to serve many industries, but by 1942 it shifted its scope in order to focus solely on serving the forest industry.

Production in the graphic arts industry increased more slowly than the average industry growth in Finland over the same period (Hjerppe, 1982). During the period the number of personnel doubled (Saarinen, 2000:58). By 1990 the printing and publishing sector consisted of many small or medium size companies and only one big firm, Sanoma WSOY. The publishing and printing sector was a field in which there was intense competition, and in printing a problem of overcapacity. In the newspaper field technological and R&D collaboration was easy because there was no competition around technological capabilities; however competition centered on content and geographical distribution. To support and finance technical research in the field the Graphic Technology Research Foundation was formed in 1960. The foundation became the key financer and coordinator of R&D projects in the sector and has held this position since that time. The major publishing company, Sanoma WSOY, held a key role in this foundation. This also influenced the institutionalization of R&D activities in the sector; this can be seen in the gradual reliance on trusted key organizations and actors. Research and development therefore can be seen to have coevolved with the industry. This said the publishing and printing sector had very little research and development activities of its own.

In 1962, university education and research in media technology was established. Importantly, funding from the Graphic Technology Research Foundation supported this development, and the establishment of a professorial position. This foundation had earlier received a larger portion of stocks in the media firm Sanoma, which generated good equity. The Laboratory of Media Technology was then established within the Department of Forest Products Technology. The focus of the laboratory was educating engineers for the needs of both the paper and the graphic arts industries in media technology. Several students that commenced their studies in the initial years progressively advanced in their respective firms to attain managerial positions and became influential in the mobilization phase of electronic publishing and printing. The laboratory had several individuals qualified at doctoral level during the 1970s who remained at the laboratory or continued research at VTT and who later became influential in mobilizing collaborative work in the electronic publishing and printing field. The first computer for image processing was installed at the laboratory in 1978. Research in digital printing at the laboratory and at VTT commenced in the early 1980s. In 1983, a change of professor took place with the then present professor moving to industry and a researcher from the laboratory progressing to the position. During the 1980s the laboratory increasingly focused on the digitalisation of paper-based communication processes. Graphical technology was then examined from the imaging science and technology perspective (webpage of the laboratory). In 1992, a professorship was established in the area of computer based printing and publishing. With the turn of the 1990s the laboratory increasingly engaged in characterisation of information technology in printing and digital publishing and net media technologies (media.tkk.fi).

In 1983 the act of State Printing Center (FI: Valtion Painatuskeskus) was enacted. This outlined steps for the privatization of the firm that later become EDITA. It was the professor from the Laboratory of Media Technology that was recruited as the director and charged with developing and implementing this progress. Investments made in electronic communication practices and techniques were taken by the firm in order to develop and secure their long-term publishing activities (www.edita.fi).

4.3.2. Cultivation and early innovation phase

> The space programmes of the two superpowers began to die down at the end of the 1960s. One of them had, instead of photography, used computers in processing the space images. As the government programmes ended, the specialists sought employment in universities and several of them wrote books on digital image processing. Furthermore, they published thousands of image processing algorithms that had already been tested in practice. At the same time, the concept of image science was born as mathematicians, information technology scientists and photography scientists began public scientific collaboration. The Laboratory of Media Technology adopted rather quickly an identity of image science and began to establish connections to the international circles that were forming. (Saarelma & Oittinen, 2007)

As digitalization increasingly gaining momentum, the first ink-jet and laser printers entered the market in 1984. This marked the beginnings of the early structuration phase of ink-jet and electro-photographic print. While electro-photography was initially invented in 1938, and in its early stage developed with the copier machine, the field of ink-jet printer technologies emerged from several different techniques with similar principles invented at different points in time. The two technologies, electro-photography and ink-jet printing techniques, did not initially provide the quality and speed necessary for the graphic arts industry, but indicated the clear potential for enabling a paradigmatic shift in the industry. Technically, this foreseen shift meant a move from the multi-stage structure of electro-photographic methods to electrostatic imaging. The disruptive character of this shift arises from the shift from conventional printing methods, via plate making in the printing press, to digitalization of the printing press. This shift includes an entirely new science and engineering knowledge, and a shift in mindset to digitalization with regard to novel opportunities and user demands. This said, the shift in the graphic arts industry and paper industry did not emerge suddenly, rather it emerged slowly - *"digitalization of the production of printed products had been progressing systematically from content production towards printing for thirty years"* (Oittinen, 1999:3). Partly in response to the gradual increase and diffusion of media technology know-how, an industry project was initiated to develop printing machines in Finland. The conglomerate Wärtsilä, owners of a paper machine manufacturing unit at that time in early 1980s, progressed towards developing printing machines (interview with a researcher). In this explorative work they worked simultaneously with several printing techniques. This exploratory work did not succeed and further plans ended.

But it was only when the first larger and higher speed ink-jet and laser printing presses appeared at international trade fares in 1993 that the actors in paper and graphic arts industry and media technology started to pay more careful attention to this emerging technological field, and the resulting opportunities and threats. This initial structuring phase was also driven by the increasing penetration of internet and computers. Finland had been a forerunner in embracing these new technologies. By 1994, Finland ranked number one in the world on measures of internet hosts per 1000 inhabitants (Network Wizard, Internet Domain Survey) and 17% of households in Finland already owned a computer. These developments partly contributed and supported an arising awareness of the emerging opportunities and long-term foreseen shifts in the industry and market dynamics of traditional publishing and printing.

With the developing awareness, actors had increasingly started to identify the emerging opportunities offered by digital printing and how it would enable this kind of printing in small quantities, including short-run-printing and on-demand printing. It was also foreseen during this phase that with inevitable technological progress of these techniques, digital publishing and printing would gradually increase to compete with traditional offset printing methods. The developed technologies, with their increasing technical and economic performance, provided opportunities for decentralized printing as well as variable information printing. This meant a shift from the previous big presses and mass delivery, with huge stocks and long transportations, into smaller and more locally based presses that provided on-demand printing capabilities and more cost efficient economics. The change enabled increasing customization of printed material. In addition, on-demand printing on packages became a focus of research and development. For end-users this emerging technology enabled high quality printing at low cost. The paper industry had been early in starting to develop papers for the new printing techniques, and moved into high end papers (so called Xerox paper). Enso Group and Metsäliitto had become a forerunner in high quality coated 'artprint' papers in digital printing.

Two dominant technological designs (Abernathy et al., 1978) increasingly showed the signs of emerging within the digitalized printing technology. Ink-jet printing was evolving to becoming the main technology in on-demand printing by smaller publishing houses, and electro-photography as the main in-house printing technology for end users. These two technologies, although very different in fixing ink and color to the paper, created new and different demands on paper quality and the runnability of paper. The coding and transformation of images to produce high quality outcomes was linked to the characteristics of the paper.

The rather small Finnish media technology community of experts in both public research organizations and industry had increasingly become active in participating in international conferences in the field; for example the international conference on Non-Impact Printing. But in this early innovation phase, research in the field of publishing and printing and media technology in Finland was rather fragmented. The VTT Graphic Arts Laboratory and the Laboratory of Media Technology at Helsinki University of Technology were not in active collaboration, though at the time located in same building and even on the same floor. This was, in part, explained by the inability of the directors to engage in collaborative research. Collaboration between the industry research center KCL and VTT, the Technical Research Center of Finland, both located at the Otaniemi campus area in Espoo, was equally nonexistent. Although the inability to collaborate between these three most central strongholds of knowledge in the area of electronic publishing and printing in Finland, knowledge in areas related to electro-photography was also increasingly identified and developed by industry and other research actors. At Helsinki University, education and research in mathematics and information processing, and at Jyväskylä University, knowledge in physics of paper-color interaction and fluid dynamics developed.

The first one color electro-photography printing press announced in 1991, and the first color digital printing press - ink-jet and electro-photography based machines both presented at international trade fairs in 1993 - made actors increasingly aware of the coming shifts in publishing and printing. This paradigmatic shift enabled variable information printing to emerge. These new opportunities had also started to become tangible and visible; some firms had started to explore opportunities of digital printing of small quantities in Finland. This shift also provided another path, were traditional publishing activities could be done on the internet. The first newspapers[37] published on the internet in Finland were published within the Otaniemi university campus in 1994 by the firm Aamulehti. It was clear that these technologies would gradually increase in competitiveness to traditional offset printing methods but when this was to occur was still unclear.

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[37] The newspapers published on the internet (within a closed network) included Aamulehti, Kauppalehti and Iltalehti.

4.3.3. Early structuration and mobilization phase

Pressures on these industries to take responsive action were arising from the increasing digitalization of production and communication, and the development of information and communication technologies. Printing and media production was closing in and becoming more integrated than in the previous mode. This techno-economic paradigmatic change (Freeman, 1988) was starting to influence, through increasing pressure, change to publishing and printing operative practices and to the predominant business model logics. In this way, this phase was dominated by several elements of uncertainties, making predictions and anticipations of the change challenging.

For the graphic arts industry, collaboration in applied industrial research had started to be established with the first national technology program, the Graphic Arts Technology Program (GAT), which targeted the sector between 1992 and 1995. This program focused on the challenges introduced by the emerging change from a printing industry into a media and communication industry, the convergence of printed and electronic media, and subsequent structural changes. This collaboration was initiated by the Federation of the Printing Industry in Finland and by the Finnish Newspapers Association. The program focused on the integration of pre-press processes, the infrastructure for the graphic branch, automation, and ecology of printed communications (Lindqvist, 1995). The program was centrally driven by industry interests; with 80% of activities located in industry-coordinated projects and 20% coordinated by public research organizations. A technology strategy for the printing industry was developed as a project by the Federation of the Printing Industry during the program. Although a research manager at VTT acted as program coordinator, the previous professor at TKK, now director at the State Printing Center, functioned as chairman for the steering group of the program. While VTT centrally led the coordinative work of the program, a renowned industry actor was thought to be important to avoid conflicts and provide legitimacy of program-level actions. As one of the interviews put it:

> The director from industry was nominated as chairman of the program as VTT was thought to be a partial actor

At the same time as the start of the GAT program, Finland plunged into economic recession. The recession affected the graphic arts industry in many ways. Firms refrained from recruiting during this time and turnover of the industry dropped, resulting in decreasing number of pages of magazines and newspaper. In addition, several firms had to end their operation during this period. Despite the ongoing recession, the program generated high levels of engagement by the industry. Small and medium size firms in the graphic arts industry especially seemed to have time to develop and innovate.

The paper industry in Finland, in contrast with the graphic arts industry, had a long history of productive and intensive collaboration between firms in both research and technology development. This was the case even though the firms competed on the international paper market. Collaborative structures and practices around research and development work had subsequently emerged; such as the joint research institute Central Laboratory and contractual practices. Although Finland's membership of the EU was opening up new opportunities for firms, it also meant restrictions in collaboration between the big paper manufacturers, especially concerning the development of paper standards.

The necessity to proactively adapt towards this emerging shift was augmented by several factors. These include; Finland joining the EU, the approaching integration of the several existing technical mediums of media and communication[38], and the increasing legitimacy for a proactive shift towards an information society. Finland's upcoming membership in European Union in 1995 was clearly going to bring with it an increase in competition, but equally growth opportunities through the opening up of markets. The Finnish government was, in addition, paying increasing attention on the necessity to proactively engage society and industry in a transition towards the foreseen emerging information society era. At the government level an information strategy for Finland was published in 1995. This outlined the necessary strategic actions required throughout society and industry. This agenda also legitimized additional funding for the National Technology Agency, Tekes, who were charged with the responsibility to mitigate this transition through national technology program activities.

This resulted in several program activities and recommendations for changes required to society and the industry. Several initiatives in the area of 'new business in digital media' were mobilized during mid 1990s in reaction to the emerging digitalization. In total, five National Technology Programs [39]were initiated during 1995 and 1996.

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[38]The media becoming more integrated included radio, TV, newspapers and magazines, and advertising.
[39]Finnish Multimedia Program, electronic Publishing and Printing, Digital Media Content Program, Digital Media in Health Care and Industrial Applications of Multimedia.

4.3.4. Field mobilization

> The advent of digital colour printing technologies in the early 1990s was seen as a turning point, which led to the conclusion that electronic printing had now reached its rapid development phase. This view was supported by the strong increase in the number of patents related to digital printing and by equipment suppliers' publicly announced strategies for challenging conventional printing methods (Oittinen, 1999:3)

This emerging awareness was reflected in the initial explication and probing for a national technology program in electronic publishing and printing. The probing partly came from a research director from one of the three large paper manufacturers and partly from a professor at the Laboratory of Media Technology. Knowledge related to the emerging technological field had developed within the Laboratory of Media Technology at Helsinki University of Technology, at VTT within the Information technology laboratory and the Graphic arts laboratory, and at the research institute KCL. With the increasing field-level awareness among researchers and among industry actors the research director from the large paper manufacturer urged the need and the value of collaborative exploration and exploitation within the emerging technological field:

> I kind of incited the professor at the Laboratory of Media Technology at Helsinki University of Technology that a program should be initiated and this was then accomplished

This episode thus seemed to in part have triggered the initial mobilizing. It sparked the undertaking of an initial background study by the laboratory on the emerging technological fields for supporting further mobilization and legitimation. The central idea in this initial stage was to support the prevalence of paper based communication, thereby embedding the new technology with the predominant technology specific logic:

> Increasing paper based communication and documentation in increasingly digitalized information transfer… this program supports the endurance of paper and to develop paper as information intensive communication data platform (excerpt from planning document of the program 1994)

This initial framing addressed sustaining the competitiveness of the forest industry around the emerging technological field of electronic publishing and printing. Specifically, digitalization was seen as an emerging new channel for transferring data, but the awareness of how and to what extent the emerging structure and its properties would enable novel practices and interfaces to emerge was not clear. As these two excerpts illustrates:

> Computer networks were primarily seen as channels for transferring data to printing shops. The views brought up in the planning phase are reflected in title of the pre-study of the programme area: "From computer network to printed product"(Oittinen, 1999:3)

> Digital publishing or electronic publishing – whatever term was used at the time – as a concept was primarily associated with digital storage media, not web-based publishing. The development of Internet-based communication into its own medium was far from obvious at this stage, though the Internet began to attract widespread attention in mass media at about this time (Oittinen, 1999:3)

The paper industry was becoming increasingly aware of emerging changes that came with digitalization. They pictured that at this stage digitalization included shifting costs structures in paper and cardboard exports. The ongoing developments in information technologies would thus enable packaging and "coding" to take place at the end of the logistics chains. Equally, strong environmental pressure that the paper industry had been grappling with provided rationalizations in the industry that concluded that changes in the value chain were forthcoming. As one of the researcher directors at a big pulp and paper firm described:

> At the time there were also quite strong ecological pressures and it was then rather natural to save in terms of logistics and in terms of material waste from over production…this was what we were talking about in industry…we did not think the technology was insurmountable but the value chain was just being reorganized in a different way

This initial probing within the paper industry and graphic arts industry soon made apparent reluctance, especially within the graphic arts industry. To overcome this reluctance a meeting to enforce and legitimate collaborative activities within the emerging field was held at the office of the dean of Helsinki University of Technology. The dean, a distinguished professor in automation, had close relationships with the paper manufacturing industry, which, in addition to his position, provided further legitimacy for this probing. This meeting, and the reliance on an authoritarian type of social mechanism and the advocacy through social suasion (Lawrence et al., 2006), contributed to the intended support for the mobilization. As one of the interviews described:

> When the dean put his authority into the planning and initial mobilization it got the industry and the firms on the move a bit better, but despite this meeting it took another two years for the program to start…even though ...the plans for the program were rather far developed and we were prepared and presented what was to be done

Planning thus continued in collaboration with VTT Information technology laboratory and VTT Graphic arts laboratory. A larger planning seminar was then held a few months later in 1994 where 40 central actors from the two industries and from public research organizations, as well as from public organizations such as the post office and representatives from Tekes were brought together. In these initial plans a central rationale from the paper industry was to develop a test platform at the Otaniemi campus area where prototypes from leading printer manufacturers would be tested before they entered the market. Interestingly, the research institute KCL was not present in this early planning phase. The absence was explained by one interviewee as due to the emergent institutional contradictions arising from the novel technological opportunities in electronic publishing and printing and the acquisition of resources and influence by research groups within this emerging field:

> We were not participating in the planning phase….we then with "long teeth" engaged when the program started…. And they had staked the research field and we got to explore what was left in research topics….in this initial planning our owners were present and therefore all thought that we were not necessary when the owners were there keeping our side and then the owners at one point said to us that KCL has now to participate in the program … but I think that during this time it was a clear competition about research subjects between us and our research companions at the Otaniemi campus and I think this was emphasized during the planning phase of the program

This shows how the emerging shift also created tensions about reclaiming position in the emerging paradigm towards industry in the research community.

By early 1995 a pre-study for the program had been carried out by the Laboratory of Media Technology at Helsinki University of Technology and the VTT Information technology laboratory while as earlier indicated KCL had not been invited to this planning phase. The industry actors who were interviewed, described this pre-study as very detailed and very technology driven, but there were no assessment of the business potential. Equally, this critique included reference to researchers being too central in the mobilizing of a national technology program that previously had dominantly been industry driven. As one interviewee explained:

> There was critique from the field that now the researchers were mobilizing and planning a program, and especially the graphic arts industry, that the technological fields was in its infancy and too early to engage from their point of view

This indicates that researchers outlining elements that were to be attended to in the structuring of the emerging field, reflected the global developments in digital publishing and printing and in digital media technologies, which were translated into the contexts of the two targeted industries. In this way the symbolic system, including classifications, categories, and the expectations of electronic publishing and printing that was drawn upon, was much further developed among researcher than in the industry. This created tensions in terms of communicating and matching the two industry-specific prevalent symbolic systems with the emergent symbolic system within electronic publishing and printing. In the same way, the technological artifacts that had started to emerge provided different meanings and interpretations to those actors that draw on the emergent symbolic system than for those that relied on the existing one in each respective industry setting. To this extent, the emerging change created ambiguities and diverging views of the coming shift. As one of the interviews put it:

> Electronic publishing and printing was by some thought to mean solely electronic publishing, and we understood it in the beginning as from computers to paper and other publishing materials …and then there was this multimedia program that at the same time was starting to formalize where there was opinions that no paper was needed anymore, at least the word press would disappear, and that multimedia would displace everything … this was what the fight was about

Despite contestations, the preparation for the program had advanced and in the summer of 1995 the program finally was approved as a national technology program with annual budgetary commitments from Tekes. At the same time VTT had a larger organizational change and the Graphic Media Laboratory was integrated into the Information technology unit, which in part, further reflected the contestations between two different technological communities during the program.

4.3.5. Field structuration phase

The national technology program Electronic Publishing and Printing (EPP) started in the autumn of 1995. The goal of the program was crystallized as to advance the development and adoption of digital printing and promoting R&D activities regarding paper quality and business concepts around the development of digital publishing. More specifically, the program strategy outlined the development of business activities and practices as well as expertise within the emerging technological field. As this excerpt explains:

> The EP programme was designed to promote business activity in the area of digital printing and the related digital publishing sector, to speed up the development of working procedures and the introduction of applications, and to facilitate the development of new products and expertise in this area. (Oittinen, 1999:3)

The rationale for the program from the technology policy perspective, and for attracting industry participation, was the possibility for establishing an early lead-market around the emergent field. The context and market conditions of the Finnish publishing industry, with a rather small population of Finland and small quantities of prints, provided favorable conditions for developing and testing the new technologies and possible business models. In addition, the advanced communication infrastructure in Finland and the low population density was argued to enable innovations in the domain and to facilitate the formation of a lead market in electronic publishing and printing (Oittinen, 1999).

A steering group for the program was nominated by Tekes in 1995. It included director-level representatives from the three major paper firms in Finland, four directors from the most influential graphic arts industry firms, a program coordinator from The Laboratory of Media Technology, and two representatives from Tekes. The most influential players from the two industries in Finland were hence represented. The program coordination was divided between three women in what were highly man-dominated industry sectors, including the professor from The Laboratory of Media Technology at Helsinki University of Technology and two experts from Tekes, each with a long track record within the predominant technological field. Researchers responded directly with concerns on the choice of board members who would have a central role in both initiating and evaluating research projects proposals in the program. Specifically, they were doubtful about the expertise of the steering group within the emerging technological field of electronic publishing and printing. As the following excerpt from the first steering group meeting explains:

> At the research side there is prevailing "great astonishment" about the composition of the steering group. Researchers have brought up the concern about adequate awareness of industry representatives in the steering group (steering group minutes of meeting in September 1995)

This indicates that researchers had doubt about the capacity of board members from the industry to productively envision, contribute, and direct activities and incentives around the emerging field of electronic publishing and printing. As this was not further addressed by the board, it also indicates how the strength of awareness is not directly related to the relevance for an actor to engage and commit oneself to explorative action around novel technologies.

At the start of the program a call for proposals was organized that attracted many collaborative research projects. Although the printing and publishing industry had started to recover well (annual growth of 4%) from the economic recession (Saarinen, 2000), the incentive and interest of engaging in research seemed to decline. As one central actor at VTT explained:

> When the subsequent program for the graphic arts industry started it was much more difficult to activate industry as the economic situation was much better and the industry did not have time to do as much research as they did in the early 1990s

A contract agreement with regard to collaborative industry and research projects within the program was carried out in the initial phase as a normal procedure for starting national technology programs. This contract, to be signed by all actors participating in collaborative projects, included stipulations about ownership and use of the results from collaborative projects, about inventions, and the publicity of results and the role of the project steering group. In total 15 research projects and 17 product development projects were subsequently funded during the program.

During the early phase of the program the active research manager from a paper manufacturer pushed for collaboration between the three large firms in the industry as a means to develop a common standard for the use of digital printer paper This proposal did not seem to receive adequate industry interest to proceed. As the director explained:

> This message did not go through in the two other firms….I'm not sure whether they did not prioritize it so that there would be those guys in the board of the program that would have been able to negotiate in their firms because I think that the marketing side would have understood this…but there was these cartel restrictions as we were entering the EU and it was not possible anymore to gather the marketing people from the three firms and agree let's do this…and in that sense one would have needed to go through the technology side; and I discussed this in Brussels and it was fine for them to do just as the mobile phone industry had done with their standardization.

To this extent quality requirements for developing papers in digital printing did not develop in a dimension that emphasized economy of ink, but rather on other physical properties of papers. Development of papers that would minimize the use of ink was certainly possible from the engineering perspective. As a research director from industry put it:

> We could have made the paper so that it would not have used so much damn ink.

A digital paper standard could have been a value adding property and a product diversification strategy for the paper industry. For the paper industry a standard in digital papers would have been beneficial. As the director explained:

> The Finnish paper industry could gain a competitive advantage from developing a "digipaper" use standards which we could develop so that they would fit with our paper production techniques and existing processes, and that would be harder to implement somewhere else

But printer manufacturers were developing a 'razor and blade' business strategy[40] in digital printing through low printers margins but high margins from ink-cartridges. Therefore, the printer manufacturers that owned ink-cartridge manufacturing facilities had no interest in supporting this development but rather, wished to develop their own paper standards. Although there was reluctance towards standardization, the collaborative logic of innovation that had prevailed in the forest industry for a long time was still present. As one Tekes expert illustrated

> There was, on the industry side, still the remains of that kind of previously dominant collaboration, which after this program then quite dissolved; I mean these three happy bandits (referring to the three major paper firms)

The program followed an established progress of national technology program activities managed by Tekes. During the initial stage of the program, the focus was on activating public research project within the area of the program. Helsinki University of Technology therefore set out to focus on picture manipulation techniques and enhancing quality of pictures and algorithms. VTT focused resources on ink-jet and surface chemistry. In addition, the value chain

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[40] With a razor and blade business strategy, part of the product is given for nearly free while the necessary other part is costly and necessary to displace frequently, thus providing steady revenue income for the seller.

of the industry and 'runnability' of paper with the new techniques were themes that triggered project activities at VTT. At this initial stage firm participation in research projects was much harder to attain. This was partly due to the low-level of awareness of the emerging paradigmatic shift. As one interviewee explained:

> Some large firms that were approached to join research projects said that this is too far from their activities (digital printing) and evaluated that it was so marginal at that time. Today they might have another opinion on this, but …

To picture the emerging technological paradigm and the tendencies for a certain technology specific logic and related business logics seemed to be problematic. As an interviewee recalled concerning a steering group meeting of the program, which discussed a project on developing photographic papers that had been submitted by the Media Technology Laboratory at Helsinki University of Technology:

> I remember that we were talking about these developments and agreed that people will not start printing photos and that they will only start printing pictures on normal paper and all three paper firm representatives agreed that this was not relevant

Opportunities were also interpreted to be directly implementable without institutional embeddedness. This became apparent with the development of teaching materials that, in the initial phase, had been foreseen as one of the key areas in which these technologies would be highly valued and therefore function as a lead market. As one of the interviewees elucidated:

> Tailoring of teaching material was widely assumed to be what the teachers really wanted and needed, but piloting of these for schools showed a very different side of it…teachers did not want to tailor as it increased their workload…they wanted ready printed books

Technologies were therefore seen to be embraced without considering the transition from the existing institutional carriers of the paper centered technological fields, with their organizational practices, technological artifacts such as the book, the symbolic system, and the relational structure, to the emerging field of electronic publishing and printing. Activities to defend the existing institutional structures were also reported. As one interviewee put it:

> At a very early stage we already started discussing this school book field that would naturally suite emerging technology and digitalization while instead of giving a school girl or boy a huge pile of books that are very costly it could be done by digital printing one book instead, where all material for the term would be included….and this did not fall on anything else …this was a brilliant idea….this damn student book cartel marched to the Ministry of Education and had dinners and sauna evenings with such an intensity that this idea has not gone through even by today (2005)…I have said this publicly many times and they only blush but this is what it is all about…

This indicates the emerging and foreseen changes in technology specific logics challenged the existing institutionalized structures and incumbent positions. Ambiguities related to shifts in the carriers of institutionalized practices, for example concerning royalties and publishing, developed into defensive behavior, in contrast to explorative and double-loop learning type processes (Argyris, 1976). Uncertainty about the evolution of cost structures around the new printing methods kept industry actors alert with regards to investments that could be outdated by more effective machines. Further development of the field was subsequently hampered by the resultant contradictions of technology specific logics that the novel technological field triggered and the uncertainties with regards to how much the new technology would progress in terms of cost efficiency.

While impeding strategic actions towards the emerging field, there was equally over-optimism about forthcoming change. Time to adapt and the necessity to consider more carefully the emerging possibilities were not sufficiently addressed. Therefore, bridging between the old and the new technology specific logic could not develop in a productive manner. In addition, the factors that would become limiting and function as bottle-necks, and in this respect direct, pace, and provide clues for productive embedding of novel technology specific logics and the identification of early lead market applications, were unclear. This is shown in this reflective review of the program:

> The emergence of digital printing in the current stage of development as a manufacturing process for short-run printed products was foreseeable as such. However, the material cost-related to digital colour printing was not expected to become a limiting factor for the competitiveness of this process as it has turned out to be in practice. Also, printers' expectations regarding their customers' readiness and willingness to provide print-ready digital contents have been to some extent overoptimistic. In other words, there are bottlenecks hampering the creation of an automatic digital pipeline from content production to printed product (Oittinen, 1999:4)

During the program, several activities aimed to advance and strengthen international links to central actors in the field and to increase awareness of the emerging technological field unfolded. These emerging structures enabled changes of innovation specific logics towards international and open innovation type innovation logics. Two larger technology field study trips were arranged, which included visits to firm and public research organizations. These tours to the U.S. in 1995 with 17 people from both industry and public research organizations, and a later trip to Europe with a smaller group of actors, provided inputs for further exploring and concretizing present state of the art in the area of electronic publishing and printing. This excerpt from the U.S. field trip memo illustrates this:

> The week long journey to American firms has grown technology optimism …the trip increased knowledge and awareness about future possibilities were reinforced … for example the belief in the broadening areas of use of digital printing was confirmed and the growth of terminals and the intensified networking between home and school strengthened (report from field trip/VTT Information Technologies Laboratory, 1996)

In this regard, on the one hand, these field trips supported the development of the symbolic structure with related expectations about electronic publishing and printing, and on the other hand, challenged the symbolic value of the prevalent technological artifacts within the paper-based technology-specific logic. Research collaboration with Hewlett Packard (HP) and longer-term research exchanges with them developed as part of ongoing research projects. This was partly possible due to the international recognition already developed, established research, and the firm relationships developed within the field in Finland, all which provided access to the new technologies before they had entered the market. As one research director from VTT explained:

> We had this 'carte blanche' that meant that if we from VTT would go to any firm who knew us and reads our reports we would get in. This was also necessary because when you study a new technique like ink-jet then you need to know the material producers in some way. And we did get into a rather good collaboration with ink producers though they are totally confidential ….and these projects were a really good alibi to approach them like "here we have this project and here are our research reports and this is our recent conference presentation which should interest you and now we want to come and talk about these and these things"

These industry relationships strengthened during the program and initiated ideas for more in-depth collaborative research structures:

> There was also initiatives for larger research collaborative structures but these did not materialize as it would have included one or two paper manufacturers from Finland and the printer manufacturers did not want to be in collaboration with single firms or especially a single country …they did not want to be marked in public…they do have, of course, private collaboration but they did not want publicly these type of research collaborations (research director from a research organization)

This report indicates how exploratory research is importantly fed from global participation and inputs from researchers. It also shows how developments of the relational system are based on both social capital and legitimacy. Non-partiality with regard to technical standards and technologies is critical for providing legitimacy and attracts needed public research actives. The printer manufacturers seemed to have gained a stronger position in relation to the paper industry with the emergence of electronic publishing and printing, which in this case influenced how research was to be organized in the field.

After the first two years of the program, increasing attention and resources were allocated to activate industry-driven pilots and technology development projects in the emerging field. Small and medium size firms in publishing, packaging, sticker and form business, and direct marketing were particularly targeted. The initiated firm projects provided increasing insights into the value of the emerging technologies of digital publishing and printing and possible business logics. On-demand production of manuals for consumer electronic devices provides an illustrative example. Prior to this, with regard to manuals for consumer electronics devices, there had been problems with matching devices with the correct number of manuals needed in different languages. With the advent of on-demand printing the publisher could access the production stocks of devices and at the same time acquire the manuals electronically directly from manufacturers. The publishing and print houses could therefore decide the required number of manuals and their respective language editions. In this way the manuals that are produced are always up-to-date and match production.

At the same time several major consolidations within both the paper and the graphic arts industries took place. The pulp and paper firm Enso, which in 1996 had formed from a merger between Enso-Gutzeit and Veitsiluoto merged in 1998 with the Swedish owned company STORA, to form Stora Enso. In the same year, two major media firms formed; Sanoma-WSOY and Alma Media. Within these companies there was a fusion of printed media and electronic media. This had an impact on the planned pilot projects in electronic publishing and printing within the graphic arts industry, which, due to the intensified competition, no longer gained the much-needed support from the two firms.

As the program was ending a survey was sent to all participating firms that asked for possible themes to pursue that would be of interest to both the graphic arts industry and the paper industry; curiously no suggestions were submitted. Through an examination of the case analysis several possible reasons for this can be identified. These are examined in the later cross case analysis.

4.3.6. Electronic publishing and printing in 2005

After the program, several investments were made by publishing firms in which some embraced the new technology and some relied on the old. This also created some bad investments within the industry. Based on the predominant technology specific logic a facility and press was built in Finland by one firm, while another publishing house bought new Xeikon printers with nearly equal outputs and roughly one tenth of the cost. This indicates that awareness in cost-effectiveness and quality outputs and the required routines and practices were not evenly distributed. In addition, acquisitions and industry reorganizations took place during this phase. A forerunner firm in digital publishing and printing in Finland, Hansaprint Ltd., acquired a competitor in the business, the firm Dark, in 2005. Through this acquisition and through organic growth from 1995 to 2005 the firm's turnover had increased from 51 MEUR to 208 MEUR. A merger between Flowman and Sypress, two firms in the software business within the graphic arts industry that focused on supporting production and automation, took place in 2003. The merger supported the development of the firm towards providing a service-oriented media business. Together these few, but for the field significant, mergers provided increasing capacity to enable industry practices and the exploration of the emerging business opportunities in electronic publishing and printing. These developmenst supported the formation of the relational system and organizational routines in the emerging field of electronic publishing and printing. The symbolic system, specifically related to the classifications, typifications, and schemata of the field had also begun diffusing. Projects that commenced during the period of the program had, by 2005, generated 30 Master Theses and 10 licentiate and doctoral theses within the field of electronic publishing and printing.

After the program the paper manufacturer M-Real moved its digital printing paper development work to Germany and Sweden. Development of valuable industry relations towards international manufacturers advanced from relationships that were initially established by research institutes; for example, the establishment of industry collaboration between Scitex Digital Printing (based in U.S. Dayton) and M-Real (source: interviewee). Stora Enso and Xeikon formed a joint venture that formalized in early 2000, whereby Stora Enso purchased a Xeikon printer for testing and developing paper qualities. This industry collaboration had emerged through previous research collaboration between the Berghuizer mill in Holland that was owned by Stora Enso (at that time still Enso) and Xeikon. In 2003 Stora Enso then further strengthened its development capacities within electronic publishing and printing when they established a digital printing paper development unit called InnoCentre in Imatra (Finland) with an initial investment of 4 MEUR in machinery and equipment. In this regard, they provided visibility and further supported the development of practices and skills of innovation in electronic publishing and printing. The following year another test and development center, the Future Printing Center in Raisio, was established. This center was joined with the established Coating Technology Center as a developing and test press center – *"including the several stages of paper manufacturing from plain paper to after processed end products"* (www.fpc.fi). The center was established by the chemical company Raisio Chemicals Oy, a forerunner in electronic publishing and printing - Hansaprint Oy, a filler and coating pigment producing firm used in the paper making process -Omya Oy, a Finnish owned global paper machinery producer -Metso Paper Oy, and a printing ink manufacturer -Flint-Schmidt Finland Oy. This reflects that both relational routines and practices in innovation logics within the emerging technological field were strengthened by formalizations of innovation logics within the emergent technological field.

The specific role of researchers as institutional entrepreneurs in the emerging technological field was symbolized by the receiving of the highly prestigious Michael H. Bruno Award, which is granted by the international community within the field of Graphic Arts, by a key researcher at VTT in 2005. During the program this researcher had worked at VTT and later had advanced to become director of research and development for the Federation of the Finnish Media Industry in Helsinki. The award was given, as stated in the official nomination announcement *"in appreciation for her dedicated services and contributions to the international graphic arts community"* (www.taga.org). The specifically highlighted the coordinative work that the research had consistently been doing within electronic publishing and printing field:

> She also works to encourage companies, organizations and even countries to coordinate and share their work for the advancement of the industry. She constantly promotes the value of cooperation between various R&D organizations and has pioneered efforts to coordinate joint international projects between her native Finland and Russia, Scandinavia and other countries within the European Union (Taga website, 2005)

In 2004 Avantone Oy, a joint venture between Metso, Nokia and Hansaprint, was formed that focused on *"interactive packaging solutions for integrated marketing communications and brand authentication"* (Talouselämä, 2004). One of the central issues the company specifically addressed was that changes to existing processes would be minimal. To this extent the firm emphasized a design strategy that considered institutional adaptation of the novel field-level logic to the predominant logics. This suggests that the program had, in many ways, exposed the challenges of the transition from the prevalent technology specific logic centering on paper to electronic publishing and printing. In this regard, this example shows how, through the program, actors had become aware and sensitive to the properties of institutional change and the adaptation that required attention.

By 2005 the emerging field of electronic publishing and printing had driven the predominant technology logics towards both paper based technology specific logics and non-paper based areas. After the program, the industry engaged in developing new services, new production lines, and new products that were based on technologies developed from the technological field of electronic publishing and printing. For example, large grocery chains increasingly engaged in personalized advertising business logics that had become possible with digital publishing and printing techniques, and developed logistics software programs.

The technology specific logic of electronic publishing and printing had, in this respect, started to shake free from the previous dominant carriers of traditional publishing and printing. In part this meant institutional isomorphic mechanisms such as mimicry (DiMaggio et al., 1983) gaining strength, as can be seen in the example of the personalized advertisements in the grocery industry that rapidly became the dominant logic. For part of the publishing sector this shift included the deinstitutionalization of the technological artifact and symbolic system around paper with the emerging artifacts of computers as interfaces starting to gain legitimacy. This can be seen by the rationalization of one interviewee:

> Media firms have by 2005 invested a lot in electronic teaching material such as intelligent education systems that tests students about if their answers are correct. And if not then gives more exercises and if they are they get praised…the development of good illustrations programs which in mathematics is really good.

To this extent the previous dominant technology specific logic was fragmented and gained multiple paths at this early stage of the ongoing structuration of electronic publishing and printing. This also enabled further and even more radical technology specific logics to appear which attracted the attention of both industry and research actors:

> Now there is a lot of talk about hybrid media even though people understand it a bit differently. What we understand with it is that it should enable the formation of business between two strong areas of expertise in Finland, the forest industry and ICT-sector…. there is belief in it….this printing of electronics on paper and cardboard is one thing but now there are several other areas such as coding technologies when you can print intelligent codes, invisible codes and whatever codes….and it was only after 2000 that 'printed electronics' became topical (research director at VTT)

As a good example, the Laboratory of Media Technology was increasingly focusing on the *"modeling of communication processes, and the usability and readability of display terminals and measurement-based characterization of these"* and *"image processing applications were extended to the area of personal communication"* (media.tkk.fi). The radical nature of the shift had also made its mark in the global printing press industry. By 2005 the production of digital printing machines had ceased by nearly all manufacturers operating in the previous predominant publishing and printing era, had been overtaken by the initial digital printer manufacturers in the industry, such as Hewlett Packard and Xerox.

Furthermore, the readiness to engage in more intensive collaborative industry sector strategy work had finally gained traction through the extensive probing by several actors both from the graphic arts industry and the paper industry.

> Only now (2005) have the media industry and publishing industry a common vision about research needed, and this is emerging as we are working with a technology strategy for this sector (research director at a research institute)

A target incentive, initially envisioned as a technology program Innoprint was mobilized during 2004 and 2005. Behind this mobilization was the Federation of the Finnish Media Industry. Together with the Finnish Newspapers Association they had initiated field-level strategy work and a background study on the competitiveness of the Finnish graphic arts industry. In addition, the Forest industry was centrally engaged in these preparatory works that later in 2006 resulted in a target incentive by Tekes to re-activate research and technology development work in the graphic arts industry, specifically among small and medium sized firms.

4.3.7. A synthesis on emergence of electronic publishing and printing

In this section a synthesis is carried out on the specific stages of emergence in the electronic publishing and printing field. The synthesis draws together findings about the dynamics and paths in technology field emergence, specifically focusing on the socio-cognitive dynamics and their related micro- and macro-level properties. A synthesis on stages and development of institutional carriers is presented. Thereafter, the transition between the predominant technological field and the emergent field is conceptualized. This synthesis provides the basic contextual background to be informed by the awareness and institutional entrepreneurship analysis that together provide the material for the between case analysis and the development of propositions concerning the emergence of technological fields.

Phases of emergence and developments of institutional carriers

Although the electronic publishing and printing program and the active initiatives for structuration of the emerging technological field were intended to bring together the two industry sectors in exploring the emerging field, this structuration created strategies and tension in the research community about reclaiming positions in the emerging paradigm. In addition, openness and interaction towards attending to the emerging technological field were constrained among industry actors and between research actors. Equally, there were tensions arising from the different symbolic systems between the predominant and emerging technology field professionals. This in turn was reflected in deficiencies in awareness and interpretation about the unfolding and possible paths for the adaptation of the paradigmatic shift towards digitalization. The existing institutional structures hampered the formation of new innovation processes and the formation of institutional structures supporting learning and knowledge transfer in this phase of the shift. This was particularly due to the shifting of institutional carriers of the predominant publishing field, and the resultant contestations of paper as carrier and the dominant interface between the two industries.

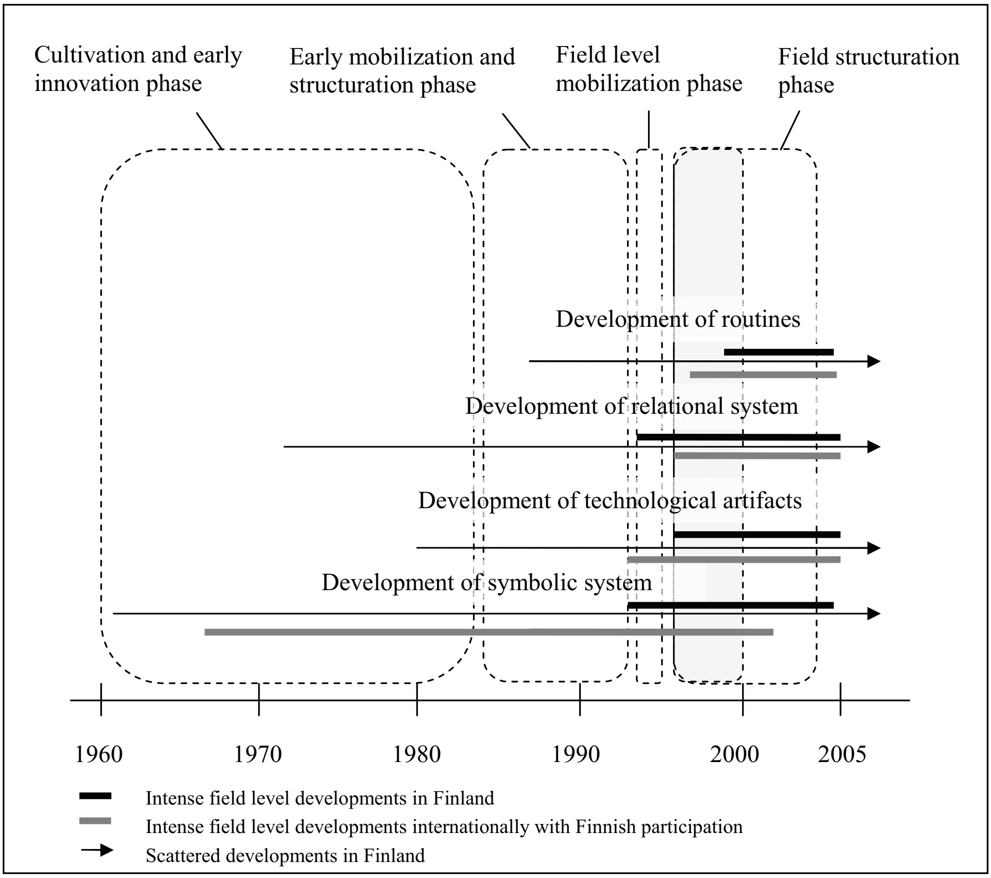

Figure 4-5 Stages of development of institutional carriers of electronic publishing and printing technology field

Institutional entrepreneurial behavior initially emerged in industry through an 'old boys' network and in research through evolving expertise by single researchers still in the process of acquiring wider field-level trust and credibility. Their mobilizing and framing of the emerging shift could not resolve the intuitional lock-in that had emerged through the evolution of both sectors. This was partly due to a lack of the necessary legitimacy and embeddedness of the relational structures of institutional entrepreneurial actors, and the unequal commitment by the two converging industries.

Shifting logics of technology field and contradictions

The program enabled institutional contradictions to emerge and made the novel technology field carriers increasingly present. This structuration subsequently provided additional support for a second phase of mobilization, where increased awareness in industry provided stronger unanimity about the necessity for action to solve these contradictions. To this extent the program created a momentum for the deinstitutionalization of traditional publishing and the institutionalization of the novel technological field of electronic publishing and printing. As the most active inputs from industry during the program came from established actors, other industry actors suppressed field-level agency. The case study also shows that a change in authority structure between key actors and a new generation of actors embodying the symbolic system of the novel field was needed before the two industries were able to shake free from the carriers of the predominant technology-specific logics. Only through active, continuous, and increasingly legitimized field-level probing by these actors were the industries able to increasingly become aware of the opportunities that the emerging field offered.

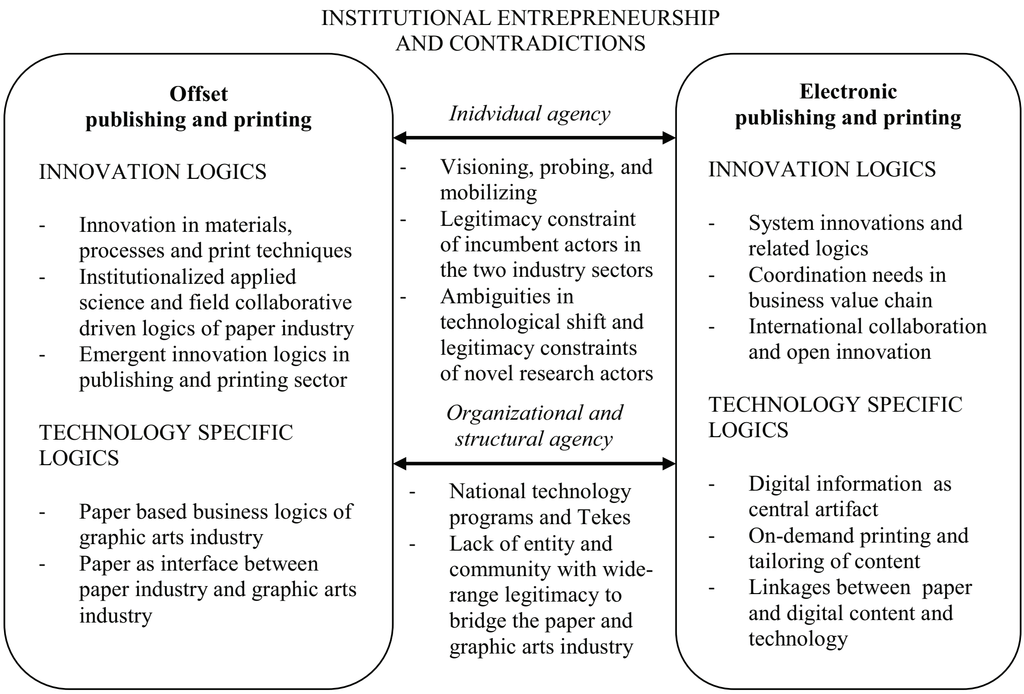

Figure 4-6 Institutional entrepreneurship and contradictions in the transition from offset to electronic publishing and printing

4.4. Emergence of well-being technology field

The emergence of well-being technology field is presented and analyzed in this section of the chapter. To account for the observed socio-cognitive dynamics and resultant institutional contradictions, the background on the Finnish health care sector is described. The analysis separates four stages in the emergence of well-being technology field: (1) an early cultivation and structuration phase, (2) a concurrent field-level mobilization and early innovation phase, (3) a first field-level structuration phase, and (4) a second field-level structuration phase. These stages are distinct in terms of the social and cognitive dynamics and properties of emergence. In each phase, the analysis aims to untangle the central social mechanisms that are present that pattern awareness, institutional entrepreneurship and the resultant institutional contradictions. Thereafter the stage of the well-being technology field in year 2005 is analyzed. Finally a summary of the emergence of well-being technology field is carried out. This addresses the development of carriers of the field and distinct properties of the shift in technology-specific logic and innovation logic.

4.4.1. Background on the Finnish health care sector

Finland has a common history with the Nordic countries in emphasizing a welfare state model in which the state takes a leading role in pooling the resources in providing welfare for its citizens (OECD, 1981). In this mode the institutional carriers are formed between the state and individuals. This model was challenged by the welfare society model in the beginning of 1980s as a response to the increasing costs of health care and the additional costs and resource required due to an aging population. In addition, the lack of opportunity for individuals to participate and engage in directing care had increasingly gained attention. A welfare society model thus emerged as a conceptualization of a social policy of civil self-management, welfare for all; welfare of a society and a reflection of the duality between state and society (Lin, 2004). The concept has since been under negotiation. The initiated shift and emergent restructuration of welfare services in health care through government incentives can hence be seen as a move towards renegotiating institutional structures. It is in this emergent state and institutional context of the healthcare sector that the emergence of well-being technology field is studied.

4.4.2. Early field cultivation and structuration phase

In 1966 the first courses in clinical engineering started at Helsinki University in the Institute of Physiology, and at Helsinki University of Technology in the Department of Electrical Engineering. With the formation of Tampere Technical University in 1967 a professorship in applied electronics was established. The person nominated to this position came from Helsinki University of Technology and held an interest in what he at the time termed bioengineering. In the following year the Finnish Society for Medical Physics and Medical Engineering was established. These initial activities were fuelled by the interests of several large firms, such as Kone, Valmet, and Instrumentarium. With the primary health care act given in 1972, health centers were established in each municipality, which further fuelled industry interest in this sector.

In 1974, funding from the state provided the foundations for a Medical Engineering Laboratory at the Technical Research Center of Finland VTT, and a professorship in biomedical engineering at Tampere Technical University at the newly formed Research Institute of Bioengineering. The Research Institute of Bioengineering had been mobilized by a few active professors, including a recently appointed professor in applied electronics. With the gradual growth of both university education and research activities in biomedical and medical engineering, research in opportunities and ways of integrating technological solutions for self-management in healthcare emerged during the 1980s. These developments in research and education in the field sparked the birth of several innovative firms that pioneered applications of well-being technologies, such as the wire-free wearable heart rate monitor by Polar Electro launched in 1982.

During this early cultivation and structuration phase, applications from research on low temperature physics by the research group of professor Olli Lounasmaa had started to develop in biomagnetic measuring at Helsinki University of Technology. This research later resulted in several commercial applications. Concurrently, pioneering research and development of patient data systems emerged at Kuopio University that resulted in the Finstar and the Musti information data systems. These systems were developed in collaboration with firms and spread widely to health care centers and hospitals in Finland during the 1980s.

In this early phase the medical and biomedical technological field struggled for legitimacy, especially with regard to funding for research. As the laboratory head of the Medical Engineering Laboratory retrospectively explained:

> There was the underlying problem that technologies within the health care were not really within the scope of medicine nor in the scope of medical instruments, and thus it seems to not be attended to by the public research funding…what you needed so as to develop wellbeing technologies was little doctors and little technical people and thus it does not really belong to anyone

This interstice (Morrill, 2007) between the two already legitimated technological fields required the establishment of its own legitimacy. This led to advocacy of funding for the emerging field by key individuals from research. As the director of the laboratory further explained:

> Already when Tekes was established we discussed with the general director and other key people and we got a little allocation for this. And then one person was given the responsibility to take care of this health theme at Tekes but there was no bigger strategy at this point

This example of advocacy is a form of institutional work that includes "mobilization of political and regulatory support through direct and deliberate techniques of social suasion" (Lawrence et al., 2006:221). Through increasing funding research the activities within the field developed. By the end of the 1980s, ten doctoral candidates had graduated within the biomedical technology field and the Medical technology laboratory at VTT had grown to around 50 employees. Tampere University of Technology had around 20 staff members at this stage.

4.4.3. Field mobilization and early innovation phase

A major reorganization of the health and social welfare public administration took place in early 1990s. This reorganization was centrally driven by pressures and interests for *"simplification and streamlining of social and health administration, and the strengthening of social and health policy at ministerial level"* (Järvelin, 2002). With these rearrangements several government agencies were established in the area of health care and social affairs. The National Research and Development Centre for Welfare and Health - Stakes - was founded in 1992 to monitor and evaluate activities in social welfare and health care services, and to carry out research and development in the field (Järvelin, 2002).

Early innovation activities

At the newly established agency Stakes researchers working generally around the theme of 'social technology' had became increasingly aware of the possibilities and solutions that could be valuable in this ongoing shift in the health care sector. Interest in joining research and innovative work around the broad theme of self-management in health care resulted in the formation of a research group at Stakes named ITSE.

> The technologies that were brought into this context came more broadly from EU collaboration that researchers had engaged in and also through the international handicap movement that influenced a lot the focus of research that people had engaged in, and there were safety technologies, tracking technologies and general robotics (researcher at the ITSE group)

This work was preceded by a smaller research program by the Finnish Innovation Fund, Sitra on social technologies in early 1990s. As the laboratory director from VTT explained this initial phase that resulted in early formalization of research and innovation work in the area of well-being technologies:

> I was engaged in national social and health care technology matters in some committee …I was following and in part also starting some things with the folks, such as with social technology ….it was one of the first things I participated in …this was initiated at Stakes…and we defined it and one book was written about this by us and then at this stage our international networking started and then this ITSE-group was formed.

This pool of expertise had mainly increased in response to both macro-level shifts in society and micro-level interests, and the development of awareness among actors within the emerging well-being technology field. The ongoing shift in both health care policy and the emergence of an information society defined both the opportunities and the problems that needed to be attended to. Equally, awareness and interest in the technological opportunities that would provide support to handicapped and elderly people in trying to master their lives with restricted physical and psychological capabilities and to become more independent and capable within existing mainstream technological designs had developed. The ITSE-group rapidly started developing cutting-edge inventions and solutions that gained acknowledgement and visibility and high interest. The work at the ITSE-group was soon also extensively linked to industrial actors, especially firms from the mobile and telecommunication industry. Although the group was located in Stakes it had no organizational routines that would have supported it in these emerging endeavors. Still, it managed to build up extensive knowledge and expertise in the area and their solutions were tested by big industry actors in consumer electronics:

> And the craziest thing was that this ITSE-group lacked all those capabilities that you need when you collaborate with firms, this is dangerous to say but there were no practices for dealing with for example secrecies …but what we worked with was highly sophisticated things including usability research that was central in this group. (a researcher from the ITSE-group)

The application and usability dimension came from a very active researcher at University of Art and Design Helsinki (TaiK) who came to be very closely related to the ITSE group. As one researcher from the ITSE-group explained:

> She was from TaiK and she was really intensively participating in our projects, I would say not one day without her in the ITSE group …and it was really high-level this work and research on usability

To conclude, these early innovation activities were driven by many ad-hoc activities that brought together individuals interested in pursuing an awareness arising among these actors of the opportunities with well-being technologies. With these activities, technological artifacts were increasingly starting to form around the emergent well-being technology field, starting to agitate prevalent conventions and specifications within health care field mobilization.

Concurrent with the reorganization of the health care administration and the emergence of initial innovation activities in well-being technologies, deregulation of the health care sector was instituted. In 1992 the law for public procurement came into force. This law made legal and provided direction for outsourcing of services in health care. The following year a new act led to substantially modified financing of the health care sector from a system of separated allocation to primary and secondary health care to a system of demography and municipality based allocation. Hence the new financial scheme gave municipalities more responsibility for allocating and organizing health care. This reduction of regulation shifted the role of the Ministry towards a prime responsibility for 'steering through information'. This meant governance through "policy recommendations based on research and evaluation, evidence-based medicine and protocols, education and training, performance indicators and other activities based on information development" (Järvelin, 2002:14). Although these newly instituted incentive structures for deregulation provided avenues and directions for increasing efficiency of the health care sector, responsibilities and the role of customers were still largely ambiguous. This was due to the overlapping and poorly defined roles between municipalities, the population, employers, KELA (the state benefits and social security department), and insurance firms. To this extent the market mechanisms for healthcare services were undeveloped; as this excerpt illustrates:

> The role as a customer is divided among several actors….the one who pays can be the municipality, the state or the insurance company …there is therefore this situation where the service or treatment of a customer requires different actions from several actors and at several levels and in several locations…this causes boundary problems and the fragmented system obscures the completeness and no one has this broad-level awareness (free translation from: Södergård, 1998)

The increasing applicability and opportunities of information and communication technologies enabled a second paradigmatic policy movement. This policy movement addressed the emerging information society in the early 1990s. This culminated in 1995, in a government program that outlined an information society strategy for Finland. This government plan also included a national technology strategy for the development of new technologies and the building of information infrastructures. The Ministry of Social Affairs and Health appointed a committee and a secretariat that was then given the task to write this information and communication technology strategy plan for the health care sector. The secretariat was formed by individuals from Stakes. Tekes took an active role in the committee work and in the formulation of the plan. This plan was implemented during the latter half of the 1990s and coordinated by the Ministry for Social Affairs and Health.

During the same period a third policy movement, the cluster model idea by Porter (1990) spread among central Finnish industrial and policy actors. This resulted in several analyses of the Finnish economy and existing industry clusters and possible emergent clusters during 1993-1995, which were commissioned by the Ministry of Trade and Industry (MTI). These studies were subsequently translated into several cluster programs. It was during this early phase that discussions between the general director of Stakes, the state secretaries of Ministry of Social Affairs and Health and Ministry of Trade and Industry, the director at the Medical Engineering Laboratory at VTT, and the CEO at the largest pharmaceutical and diagnostics company – Orion - converged on explicating the idea of a well-being cluster. This initiated a study to identify the prerequisites and possible incentives for enabling the emergence of a well-being cluster (Tarkiainen, 2005). Although the five representatives of central stakeholders held different points of departures and different interpretations about the meaning of a well-being cluster, they commonly agreed on the value for integrating well-being issues with business-related developments in order to mobilize a nationwide program in this field. This was the central to the proposed study (Tarkiainen, 2005). Although the well-being cluster program was initiated by both the Ministry of Social Affairs and Health and the Ministry of Trade and Industry, it was the latter ministry who took the coordinating role in the activities between the government actors. An advisory board consisting of high-level representatives from industry, government, and the healthcare sector, and a co-coordinating committee between the different government bodies was then formed in 1995. Stakes and Tekes were subsequently given specific agency-related tasks to enable developments towards the well-being cluster (Jääskeläinen, 2001).

It was at this stage that preparations for the Digital Media in Health Care technology program started. In 1995 the director of the information and communication technology unit at Tekes, engaged in discussions with several key actors, including the director, now research professor at the Medical Engineering Laboratory at VTT, about starting a national technology program targeting the health care sector. Both directors had been actively engaged in the elaborations and preparations of the well-being cluster initiatives. These initial discussions, and the mandate emerging from the well-being cluster preparations, resulted in the preparation of a national technology program with the focus on technology development and innovation in digital media for the welfare sector. With these preparations, the well-being theme came to be integrated in Tekes strategy. As one interviewee explained:

> It was at this stage with the TDM program that we got this wellbeing theme through into Tekes strategies as a kind of interdisciplinary theme

The several simultaneous drivers of change may partly explain the wide acceptance and easiness of penetration of the well-being theme in Tekes. There was also ongoing preparatory work for allocating a larger appropriation of funding that was to be distributed to the well-being cluster programs as well as substantially increasing Tekes funding during 1997-1999.

During the same period as the planning of the national technology program, the Ministry of Social Affairs and Health had started putting together an implementation plan for developing information society technologies in health and social services. During the following years they initiated several calls, pilot projects, and working groups in this domain. The structural funding schemes of the EU were also now targeted for local projects and programs within the focus of the emergent well-being cluster.

With the ongoing preparations for the well-being cluster program and the national technology program - Digital Media in the Health Sector- the association HL7[41] Finland was established in 1995. The association was founded by individuals from both research and firms in the field of healthcare information systems to facilitate system integration issues and standards development in health care in the Finnish context. The association came to play an active role in the diffusion of practices of data transfer in the health care system and in supporting an adaptive shift from paper-based patent data handling to digital patient data management. In this way, the standards, classifications, and schemes developed for digital data management within the international HL7 association were drawn upon when starting to develop these elements of the symbolic system within the Finnish context.

[41] HL7 stands for Health Level Seven which is an international standards development organization, and a member of American National standards Institute (ANSI), that "provides standards for interoperability that improve care delivery, optimize workflow, reduce ambiguity and enhance knowledge transfer among all of our stakeholders, including healthcare providers, government agencies, the vendor community, fellow SDOs and patients" (www.hl7.fi)

4.4.4. Field structuration phase

Two stages in the structuration phase are considered here; the first stages with the Digital Media in Health Care technology program and the second stage with the subsequent technology program iWell.

First phase of structuration

Tekes coordinated the Digital Media in Health Care Technology Program that ran from 1996 to 1999. The program focused on (Tekes, 2000b):

- Services supporting the elderly and promoting independent living at home as well as self-care and prevention of diseases
- Telemedicine, telecare, and teleservices
- Development of customer-oriented health care and service chains and open standardized systems
- Development of methods for processing digital information.

The program included much of those ideas developed earlier in the previous innovation phase and during the ideation phase of the well-being cluster. As the following extract from the program document illustrates:

> The guiding principles of the programme have been personal health management, extension of social and health services to encompass the home, and social and health services which support independent living by the elderly (Tekes internal documents)

The Ministry of Social Affairs and Health received a dedicated 5 MEUR for developing incentives within the scope of the well-being cluster: This was part of a larger incentive by the state for activating sector Ministry level research. Stakes was allocated some of this funding with which it started a regional pilot project in the hospital district of Oulu. Later, the Ministry decided to launch a call for a larger, so called macro-pilot project, in one of the 20 hospital districts to test on a larger scale a new information systems solution for the health care sector. All hospital districts applied for this macro-pilot. The district of Satakunta was subsequently chosen as the macro-pilot area. The choice was partly a politicized process because the Satakunta district that gained the status and financing did not represent the most advanced area in terms of human resources, industry presence, and capabilities. This decision clearly negatively affect the positive spirit and trust in the ongoing development work around the emerging and constructed ideas of an information society, the evolving new roles of government in the welfare society, and the implementation of cluster policy. Furthermore, the emerging social capital and institutional structures between key actors in the process were disturbed by this move.

Several schemes and incentives then developed during the late 1990s to advance the development of markets in the well-being field. The pilot of the home-care tax allowance scheme started in 1997, partly in response to the undeveloped markets for services in the well-being sector. This scheme was later, in 2001, implemented throughout Finland (Hämeen_liitto, 2003). The Ministry of Trade and Industry in 1999, within the scope of the well-being cluster, launched an activation incentive for actors to develop collaboration among firms and to facilitate the operation and functioning of the undeveloped service production markets. Sitra, the Finnish Innovation Fund, organized a project with the theme 'world without obstructions' (FI: Esteetöön Maailma) during late 1990s which involved around 40 small and medium size firms whose work was relevant to the theme. The main focus of the project was to support the internationalization of health care and well-being services. This included the international promotion of rehabilitation services and supporting the establishment of business contacts within technologies that supported elderly and handicapped people. As part of the facilitative activities carried out by Sitra they engaged in supporting the establishment of an e-health portal. This is illustrated in the following excerpt from one interview:

> Nokia in 1999 was starting with its lifechart.com service for providing health-related services for citizens… started at the same time in Finland and California… first focus on diabetes and asthma …other investors such as Johnson & Johnson and Sitra

This initiative imposed the portal as a novel technological artifact, which was rather different to prevalent artifacts such as a hospital or a clinic, equally challenged prevalent organizational routines and practices, and offered a rather new relational structure not legitimized and embedded within the current structure. This example illustrates how firms faced challenges in exploring these new technological solutions within the health care sector.

A preparatory study for a potential following program in the well-fare technology field that had been carried out in 1999 had asked firms what they saw as the biggest obstacles and challenges to accomplish their goals as a firm. Several challenges were described. First, there were clear challenges with providing services and products to public health care providers due to undeveloped practices and relational structures for public procurements:

> We have to our surprise realized how undeveloped service and product distribution channels are in the healthcare sector and equally at least our potential customers (service- and elderly houses) are not used to buy services. Partly this might be due to undeveloped management accounting…and in addition it is notable that the end customer of services and users and buyers are at different levels in the decision making chain (Tekes internal document - Pre-study for the iWell program)

Second, the predominant mode of health care did not encourage internal large-scale development. With additional fragmentation of the steering of the health care sector there was not much by way of relational routines and practices for advancing large scale development projects (Tekes internal document - Pre-study for the iWell program).

Third, the undeveloped markets and market mechanisms for well-being technologies were pictured as being problematical (Tekes internal document - Pre-study for the iWell program).Finally, firms within the field were comparatively small and interaction between firms seemed constrained; as was the case with regard to their abilities to invest in research and development and necessary certification work. This is shown in the interview quote:

> The fragmented field of firms in Finland, the firms operate alone and the firms are small and do not have aligned goals that would make them work together and save for example in marketing

Two ideas subsequently developed that aimed to solve the lack of coordination and critical mass of firms to provide entire health care service systems, for example for diabetes patients. The first addressed the need for firms to coordinate and align their activities through some form of coordination. The second addressed the need for 'locomotive' firms' (FI: 'veturi yritys') that would have sufficient resources and function as an integrator of different technologies and a provider of a broad service; for example firms such as Nokia, Sonera, and Instrumentarim.

By 1999 when the subsequent program planning started, several properties of the institutional environment of the health care sector, and its ability to adapt and utilize new solutions were apparent. The initial program had focused on the health care sector and the role of teleoperators and network service providers. Apparent problems in the program strategy of the first program resulted in a rethink of the focus of the following program and an attempt to try out another approach for enabling the structuring of this technology field:

> These private firm and these public operators were participating in many projects which Tekes then financed. There were good steps taken in the right direction but when the following program was discussed it became very clear that the diffusion of information technology into the health care system would not happen through the tele-operators but instead some other measures where needed (research professor at VTT)

Second phase of structuration

The planning of the program thus started in 1999 with the experience accumulated from the challenges in enabling the emergence of a well-being technological field. The focus shifted from the direct creation of a new technological structure for the sector based on systems development logic, towards a more facilitative and enabling strategy with a focus on well-being technologies. The internal strategy documents picture a central role of the program as the enabler of social mechanisms achieving coordination and alignment among firms in Finland:

> A new Tekes program could gather together with Sitra a multi firm project that seeks to look for providers for the whole chain of e-Commerce / e-Health business. The general idea could be how to do an "all e-health portals mother" where all the new technologies in this portal service for payment, e-shopping, services, wire and wireless, WAP, Bluetooth, services, equipment SW sales…the result would be a portal for the international market which would be a technology window for the world and which would be occupied by Finnish firms during the start, to which one would also actively seek other related significant firms (Tekes internal strategy document from 2000, that outlined the arguments and rationale for investments in the new technology program iWell that was to be presented to the board of Tekes for approval)

Furthermore, the necessity to further engage and invest in this endeavor was now forcefully explained:

> Finland has now the opportunity to become a forerunner or then not!!! (Meeting memo from the planning meeting of the iWell-program)

Several challenges to enabling a unified novel technology-specific field-level logic were clearly still present:

> There was this well-being cluster advisory board…in early 2000 there was regular meetings and discussions, but really we and they did not find a common action policy… the Ministry of Trade and Industry's interest how social and health service are produced, and very much they talked about how municipalities and public service producers should open the market for private actors…. the Ministry of Social Affairs and Health main interest was not in how technologies could be taken up in the service system or interest to discuss with the Ministry of Trade and Industry about the practices of production, but more interested in discussing the establishment of a technological platform for the sector…and in this way the same subject was just approached from different points of departures and no common language was found (director at Stakes)

This inability to enable the alignment between different government actors can partly be seen as a conflict between actors arising from contradictory field-level logics imposed by actors who belonged and draw on different organizational field logics. As the following two excerpts show:

> Internationalization and export is not the first priority of the Ministry of Social Affairs and Health (statement by government official at the Ministry of Social Affairs and Health from meeting memo on planning of program from 1999)

> Stakes has a hard time to picture what Tekes really is and how it could facilitate the preconditions for Stakes activities and the health care field (director at Stakes)

These arguments show how actors refuted organizational field-level logics that other actors imposed on the health care sector. These conflicts are centrally related to institutional contradictions arising in the relation system, including the identity and logic, the governance system, and authority structure embedded in the prevalent health care field. The excerpts indicate a lack of legitimacy, and even an unawareness of the rational and central logics and governance mechanisms of 'newcomers' to the field. Although Aldrich and Fiol (1994) address legitimacy constraints of organizations in the development of new industries, similar legitimacy constraints are here found for distinct organizational fields; specifically the industrial and market logic centrally imposed by the Ministry of Trade and Industry and Tekes. Both organizations thus functioned as institutional entrepreneurs for enabling the emergence of well-being technologies field.

The program focus was subsequently widened to include innovation and technological solutions in all home-related health services, automated home services, intelligent and built environments, technologies related to enhancing welfare and health in work, fitness technologies, and related supporting activities. Firm participation was extensive and included 100, most technology oriented Finnish companies, with 136 projects during the four years of the program. In total 30 research units took part and 56 collaborative research projects were initiated. The investments in the program amounted to 27,5 MEUR, of which Tekes' contribution extended to 16,1 MEUR.

The scope of the iWell-program included the creation of both technical and organizational solutions to support self-management of elderly people's health in their homes, distant medical and diagnostic services, operating and standard systems for social and health-related services and development of practices for digital data management. The challenge with the selected scope was the partly contradictory paths simultaneously embraced, one addressing self-organizing and the other emphasizing coordination and development of the technological system of the well-being technological field. The rationalization of emphasizing two contradictory paths is further elaborated below and illustrates how awareness about the emergence of well-being technology field was still rather tenuous:

> And then with iWell again there was this other, perhaps a bit unrealistic assumption when looking back, of how the world lays which arises from two thoughts, the first one was that …the name iWell also comes from this meaning 'individual wellness' and that health care services can be developed in two ways, one being that they are developed based on private demand, that the focus is on developing personally your health and taking care of illnesses and for this you build services and in this way one is not in contact with the public health care system but they are clients and with their own money do their own decisions and the health care is taken care of. And the other theme which emphasized that the public health care providers would participate in the development, so that no one pushes the technology to be used - the technology has to be part of this service and therefore one has to also invest in developing the service provision. (a research professor at VTT)

Because the previous program had experimented with new cooperative networks between technological developers and public service providers with good results but low rate of commercialization, this was taken as a key strategy linking the user and producer side to support the take up of new technologies.

During the late 1990s interest for developing Finnish health care practices and well-being technologies to international markets grew, partly through the Sitra project 'Free World', and partly through projects at Stakes who had intensified collaboration with the University of Art and Design Helsinki. A Japan-school was initiated by Finpro and Tekes in 1999 to support diffusion and take up of products and services related to welfare technologies in Japan. Finpro subsequently carried out a study on the Japanese medical and health care markets in 2000. In 2003 the Finnish Well Being Center FWBC Finland Oy Ltd, located in Sendai in Japan, was founded by eleven Finnish companies. This center launched the development of a large apartment complex for the elderly in Sendai and was based on know-how developed in Finland concerning designing and implementing well-being technologies and well-being services. These materializations and actions within the emerging field of well-being technology, informed awareness by giving sense and meaning to what well-being technologies were.

In addition, the Academy of Finland, the main funder of competitive research funding in Finland, engaged in supporting the development of the well-being cluster. During the late 1990s the Academy had started preparations for a research program on ageing. The duly named Research Program on Aging was implemented during 2000-2003, with a budget of 2.5 MEUR which was allocated to 20 research projects. Several of these research projects focused on issues related to development of practices within the scope of the emerging well-being technology field. In 2001 the planning of another research program associated with the emergent well-being technology field was initiated by researchers that aimed at addressing the rather fragmented research activities in health services and the lack of critical mass of researchers (www.aka.fi). This program, the Research Program on Health Service Research (TERTTU), commenced in 2004. It had a budget of 6 MEUR allocated by the Academy to cover the following five years. These program activities illustrate how innovation logics around the emergent field of well-being technology started to develop with the increasing awareness and interest by different stakeholders within the scope of the field.

At the time the iWell program ended in 2004, deinstitutionalization of the predominant technology specific and innovation logic had started. However, reformulation of the welfare society model and the related take-up of commercial opportunities and market evolution were only beginning to take shape.

4.4.5. Well-being technology field in 2005

By 2004 a third technology program in the well-being technology field had begun. This had an estimated budget of 150 MEUR with 90 MEUR of funding reserved by Tekes. This was the all time highest investment in a single technology program by Tekes at that time. The FinnWell-technology program commenced in 2004 as a continuation of the iWell program and the program was designed to run until 2009. The program focused on the development of technologies for diagnostics and care, the development of information technology products and systems that support care, follow-up or prevention of illnesses, and the development of operational processes for healthcare (Tekes, 2009). To this extent the focus of program activities had shifted back to facilitate system-level technological developments in the health care sector. At this phase the acceptance and preparedness to collaborate within the program framework had advanced. In addition, the central actors had progressed in reconsidering the role of other actors. This is shown in the following interview excerpt:

> In the FinnWell program, as we have a few representatives there, and there has been these initiatives from the Ministry of Social Affairs and Health that have focused on identifying what Tekes could develop, for example in relation to national standardizations and standardization work…. and there has now been these initiatives and there are also others, really these kind of collaborative arrangements that have now been generated, and in part these initiatives have also come from the bottom, from some hospital districts. Well, and now there is this project called Avointa (EN: openness) where Tekes is the main funder and the ministry is also funding it where the aim is to develop in Finland this test environment that when there is a software product is to be launched to the market and any possible user of this information system software would be able to test the functional properties of the product, especially the data security properties could be tested…this project has now started within FinnWell, and surely in a new way there has been possibilities to creatively work together (public officer at the Ministry of Social Affairs and Health)

This excerpt clearly shows how the interaction and the understanding and the legitimacy of Tekes and its program activities, from the perspective of the ministry, had advanced. Equally, Tekes had also progressed in increasingly becoming aware of institutional contradictions that the well-being technology field had evoked through the two previous programs. These developments together facilitated the alignment of action strategies of actors in the field, and the establishment of shared innovation logics among central government bodies in the field.

At the same time that the FinnWell program start in 2004, Sitra, the Finnish Innovation Fund, initiated a Health Care Program with an annual budget of 3 MEUR. The program ran in parallel with the FinnWell-technology program. The program targeted research, training, and experimental projects in health care that would advance paper-free administration in health care and seamless services, decentralized health services, and the internationalization of health care (www.sitra.fi). Sitra also participated in venture capital investments in firms within networking health services and paperless and seamless services. Together the several programs, coordinated by government agencies within the area of well-being technologies, facilitated the development and cultivation of the symbolic system in terms of standards, classifications, and regulation, and supported the ongoing structuration of the relational system and routines in the field.

By 2005, a majority of universities in Finland had health technology-related research and education activities. During the previous 10 years, several graduate schools had been established in the well-being technology field, including: the graduate school of Functional Research in Medicine, the Ageing, Well-being and Technology Graduate School, the National Postgraduate School in Social and Health Policy, Management and Economics, the Finnish Post-Graduate School in Nursing Science, and the International Graduate School in Biomedical Engineering and Medical Physics. These graduate schools accumulated an increasing number of dissertations and doctors in the field, expanding the cultivation of the well-being technology field, and raising its awareness throughout Finland.

In 2005 the number of health centers administered by municipalities[42] had dropped to 251. This was partly due to pressure related to economies of scale and partly due to challenges for smaller municipalities to maintain quality of care. At this time, the health care sector employed 523 000 people and the turnover for the whole sector was approximately 8,5 billion Euros. Of this turnover, 1,6 billion Euros was accounted for by private firms, and the rest was work carried out by the public sector. Firms in the health care service sector had, during the previous 10 years, grown in numbers from 8 000 to 12 000. The turnover had grown from 750 MEUR to 1,6 billion Euros (Industry sector report, 2006). In this respect the industry sector had evolved and grown alongside the emerging well-being technology field. The central challenge of the sector was the lack of larger Finnish owned firms that were interested in the well-being technology field. In 2003 the only large Finnish medical device company Instrumentarium - who were concerned with manufacturing of devices and services in anesthesia and critical care operations and diagnostic imaging and infant care, with sales around 1 billion Euros - was acquired by GE Healthcare. This was a clear change in the industry context. As this newspaper excerpt reflects:

> The merger is one of the most significant acquisitions in the history of the healthcare information industry and is expected to accelerate important healthcare technologies that will improve clinical confidence, medical efficiency and patient safety (WTN, October 9, 2003)

At the start of the FinnWell program a director from Instrumentarium, now GE Healthcare, was appointed to chair the steering group of the program. This clearly reflects a shift in innovation logics from a domestic-centered approach to more open innovation and global collaboration model.

[42] There were 451 municipalities in 2005 in Finland.

4.4.6. A synthesis on emergence of the well-being technology field

In this section a synthesis is of the specific stages of emergence in well-being technology field is carried out. The synthesis draws together findings about dynamics and paths in technology field emergence, specifically focusing on the socio-cognitive dynamics and related micro- and macro-level properties. A synthesis on the stages and development of institutional carriers is presented. Then the transition between the predominant technological field and the emergent field is conceptualized. This synthesis provides the basic contextual background to be informed by the awareness and institutional entrepreneurship analysis that together provide the material for the between case analysis and the development of propositions concerning the emergence of technological fields.

Phases of emergence and developments of institutional carriers

The initial emergence of the well-being technology field can be traced to many events and concurrent evolvements around the health care sector during the 1960s and 1970s. The approach taken for the case analysis and with the well-being technology field case was that the initial emergence of the field was traced back to those individuals, organizations, and groups that influenced and participated actively during field-level mobilization and structuration. Thus, the emergence of the well-being technology field is traced to the establishment of university education and research in clinical and medical engineering, which in the early phase in the late 1960s and during the 1970s was termed bioengineering and later social technologies. This field of research combined knowledge from engineering, biotechnology, and physics with knowledge of medicine. During subsequent years university education and research developed in this multi-disciplinary field. By end of 1980s the normative and cultural-cognitive elements of the symbolic system, including values, expectations, and schemata had advanced and started to diffuse with the developed research base at VTT having about 50 researchers and the establishment of a research institute at Tampere Technical University. At the same time the relational system had started to build up through the shared discourse and identity among researchers.

In the early 1990s several concurrent agendas for establishing a well-fare cluster and related incentives for facilitating the emergence of a well-being technology field had started to form. Information and communication technologies had advanced to the stage that the government outlined an information strategy for Finland. At the same time increasing concerns about productivity in the health care sector pushed public sector actors to increasingly consider possible solutions through the gradual opening up of markets in the sector. This moment in

Finland marks the beginning of debates and elaborations about the necessary changes in the health care sector and the possible paths to take towards envisioned ends. Technology-specific logics and innovation logics imposed by actors varied to such a degree that no agreement could be found between the Ministry of Social Affairs and Health and the Ministry of Trade and Industry regarding the paths and goals for the change in the health care sector. During the same phase, innovative activities emerged between several research and industry actors linked to a newly established research group ITSE at the National Research and Development Centre for Welfare and Health - Stakes. This group and network of actors experimented and innovated with new technologies in combination with health care knowledge and knowledge in design for advancing self-management in health care. These interactions facilitated the creation of artifacts that probed further innovative thinking in the use of these technologies. This suggests that the symbolic structure, the technological artifacts, and the relational system of the well-being technology field had started to develop concurrently and with increasing intensity.

The first technology program addressing the well-being technology field sparked an abundance of activities in technology development and trials to integrate new technologies into the health care sector. These new technologies challenged the existing organizational and inter-organizational routines of actors in the health care sector. With these initial trials several challenges in taking up new technologies in the sector appeared. Firstly, these challenges concerned the lack of information and data standards in the health care field and the data security challenges that were highly prioritized in the sector. Secondly, the firms lacked suitable business models and logics within the emergent technological field. Finally, to take up information technology in the health care sector would have require radical change of existing practices, but pressures to consider these more thoroughly were still lacking.

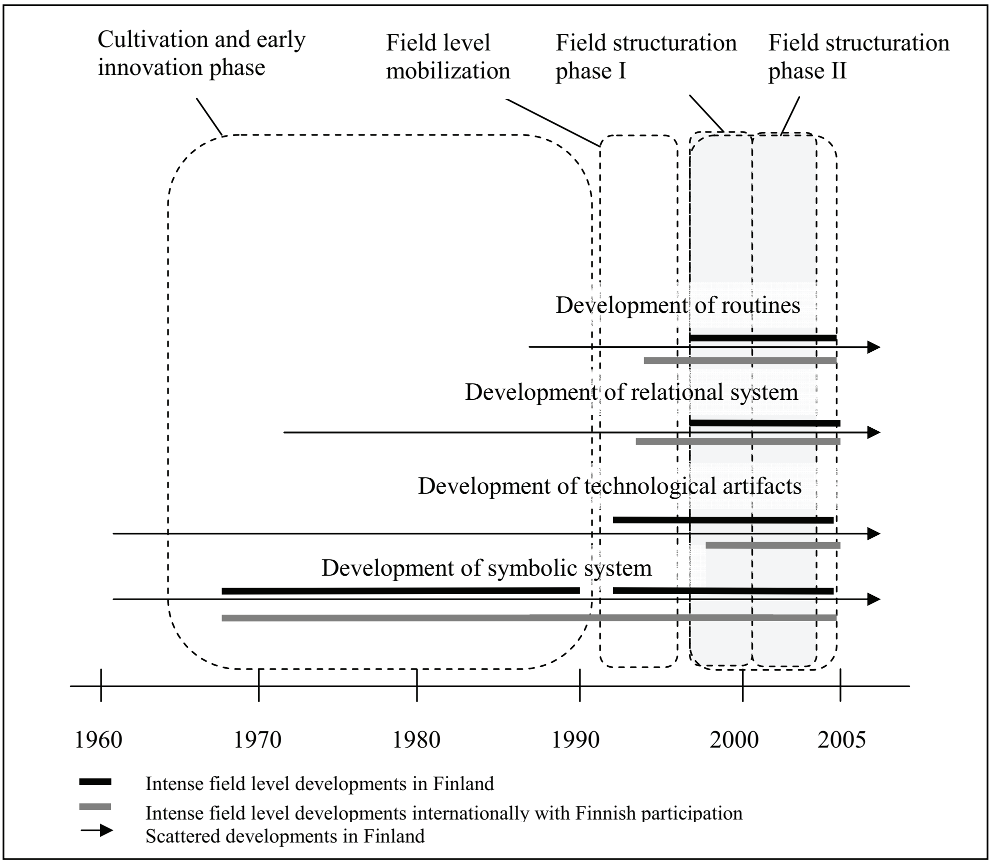

Figure 4-7 Stages of development of institutional carriers in the well-being technology field

Although the symbolic system around well-being technologies had developed among researchers, the symbolic system that would support the wider diffusion and take-up of new technologies in the field had not developed far enough at this point. To address these challenges, the second program iWell was refocused and came to address the self-management dimension of health care. The assumption was that by building on the pre-existing symbolic system of social technologies and self-management research, the well-being technology field could be advanced through this approach. While this was in part possible, the challenges about data standards and data security remained and firms came to develop rather autonomous well-being technology solutions and services. The inability to push concurrent developments of institutional carriers around the well-being technology field became evident through the apparent challenges in developing products and services for the sector, and the institutional contradictions that surfaced during the large scale demonstrations and pilot projects. These challenges provided increasingly informed understanding of the institutional contradictions and required institutional embedding measures to be taken by stakeholders. This suggests that the awareness developed from encountering institutional contradictions during the previous two technology programs supported the planning and coordination of activities around the third technology program in this field.

Shifting logics of technology field and contradictions

The shift from a public health care dominated logic towards a well-being technology field-embracing logic was related to the digitalization of health care services. At the same time the shift in Finland was related to a shift in a non-market driven service sector to the introduction of market mechanisms.

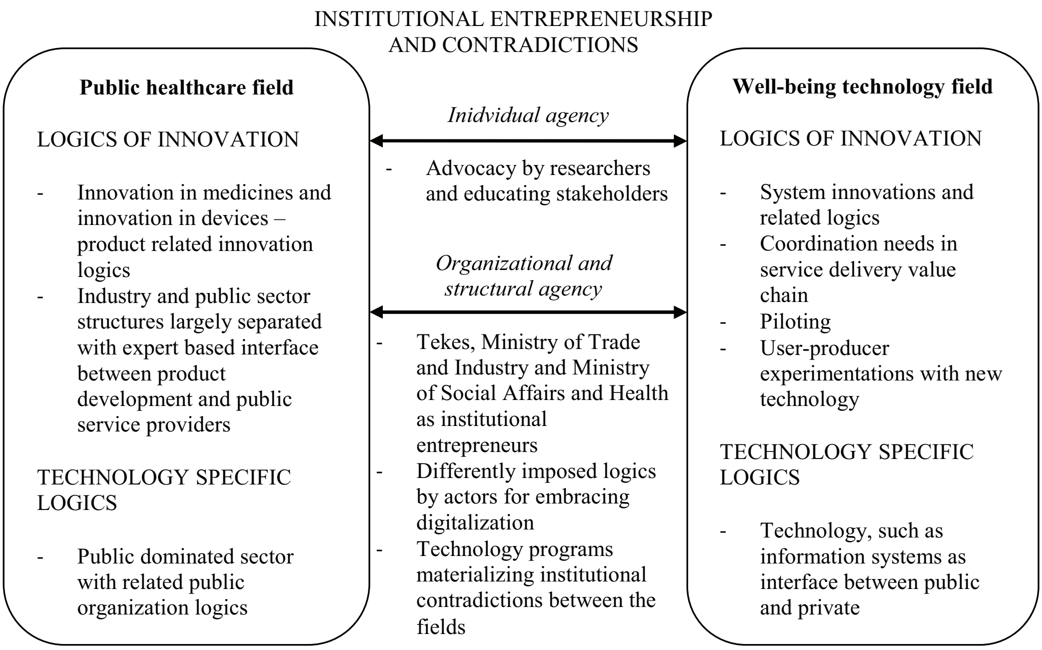

Figure 4-8 Institutional entrepreneurship and contradictions in the transition from public healthcare to well-being technologies field

The third shift that the emerging well-being field imposed was a transition from an institution based care model to a self-management enabling logic. The final change, partly related to the three previous shifts in field logics was the increasing autonomy the government imposed on health care providers, such as hospital districts and municipalities. Together these imposed shifts in logics in the public health care field generated strong institutional contradictions, materializing as the inability to understand and interpret other actors' strategies and legitimacy constraints of actors such as Tekes and the Ministry of Trade and Industry.

4.5. Cross-case analysis and synthesis on the emergence of technological fields

In this section a cross-case analysis is done on the emergence of four technological fields. First a summary table is outlined, which presents identified properties for each phase in all the cases. Then a cross-case synthesis on the stages of technology field emergence is made, specifically highlighting distinct properties and socio-cognitive dynamics taking place in each phase. Third, the four cases are compared in terms of development of institutional carriers of the emerging fields, addressing the stage of field level mobilization and the structuration phase. This is for addressing how different conditions at the field level mobilization phase influences subsequent field level structuration. Finally a cross-case analysis is done on the character and properties of the shift of both technology-specific and innovation logics and arising institutional contradictions. Together these three analyses inform the following chapters in developing propositions on micro- and macro level socio-cognitive dynamics in emerging technological fields.

4.5.1. Synthesis on stages of technology field emergence

This section draws together central properties and processes in relation to stages in emergence of technological fields, specifically addressing distinct stages of socio-cognitive dynamics, institutional entrepreneurship, awareness, and institutional contradictions found in the four cases. A summary table of each phase and related properties for all cases is presented in Table 4-1. While each the cases show various paths and emphasis in terms of identified stages, this section aims to synthesis the findings and distinguish those stages that include distinct emergent properties and dynamics though not purely present in each of the cases. The four identified stages are: (1) the cultivation and early innovation phase, (2) the early mobilization and structuration phase, (3) the field level mobilization stage; and (4) the field structuration phase. Table 4-2 then presents a cross-case synthesis on each phase and related properties of technology field emergence.

	Stage 1. Cultivation and early innovation stage	Stage 2. Early mobilization and structuration phase	Stage 3. Field level mobilization phase	Stage 4. Field structuration phase
Modular constructional steel	- Establishment of education and research - Entrepreneurial activities and first innovations to appear - Establishment and formalization of symbolic system, key elements of boundary infrastructure formalized - Learning, developing, and cultivating the classification and category structure of constructional steel	- Developments of the relational system - Increasing engagement of Finnish experts in international standardization work of constructional steel, - Developed expertise diffused both at Universities, within firms, VTT, and Rautaruukki - Mobilization within organizations and their collaborators	- Industry led institutional entrepreneurship - Legitimacy of institutional entrepreneurial activities was hardly contested in this phase - Field level probing, matching of interest, and visioning - Institutional contradictions emerge: rejections to attachment to the emerging field, and challenges in attracting construction firms	- Increasing development of technological artifacts - Technology becoming increasingly visible and perceptible - Developments of each element of the institutional carriers of the field - Inter-organizational routines and the relational system particularly developed during this phase. - Intense and frequent interaction in the field
Functional foods technology field	- Increasing awareness and understanding about the links between nutrition and health during the 1950s - Gradual strengthening of science-based education and science-driven innovation logic from 1950s-1980s. - Strengthened and widened university education in food sciences and food technologies during the 1960s and 1970s - In the mid 1970s the ‘first’ functional food innovation Xylitol, launched to the market.	- In the mid 1980s the initial attempts at mobilizing a collaborative industrial research and technology development program in the field - Public research organizations engage in European and Nordic research programs in foods in late 80s and early 90s - By the early 1990s two functional food innovations entered the market, the LGG probiotic bacteria and the Benecol and sitostanol ester that manifested the functional food artifact	- Research driven institutional entrepreneurship - Finland’s EU membership, and with the foreseen market changes, the industry increasingly engaged in growth strategies - Government set up a succession fund - Larger strategy work carried out by the food and beverage industry federation - The technical research center of Finland VTT initiated an internal research program for foods	- Field structuration activities in industry and research building on the previously established science-driven logics and the preexisting relational system between industry and research - During the second technology program corporate strategic changes, adaptations, and reorganizations - Field of functional foods gaining the legitimacy during the second program, engaging actors in productive field structuration.

	Stage 1. Cultivation and early innovation stage	Stage 2. Early mobilization and structuration phase	Stage 3. Field level mobilization phase	Stage 4. Field structuration phase
Electronic publishing and printing field	- Establishment of university education and research in media technology in 1960s - Establishment of Federation of the Printing Industry in Finland and foundation of the Graphic Arts Industry Federation to support research in the field - Development of university research and education during 1980s and early 1990s - Research in digital printing at VTT commenced in the early 1980s - The first ink-jet and laser printers entered the market in 1984	- Increasing penetration of computers and in early 1990s the rapid diffusion of Internet connections - The first national technology program, the Graphic Arts Technology Program from 1992-1995 - Finland's foreseen membership in EU was opening up new opportunities for paper industry, but it also meant restrictions in previously productive and intensive collaboration between the big manufacturers	- Paper industry driven institutional entrepreneurship together with researchers still in the process of acquiring wider field-level trust and credibility - First ink-jet and laser printer for publishing marked the emergence of electronic publishing and printing field - Arising awareness of the emerging opportunities and long term foreseen shifts in the industry and market dynamics of traditional publishing and printing	- Emerging and foreseen changes in technology specific logics challenging the existing institutionalized structures and incumbent positions - Development of the field hampered by contradictions of technology specific logics that the novel technological field triggered and the uncertainties with regards to how much the new technology would progress in terms of cost efficiency - Changes of innovation specific logics towards international and open innovation type innovation logics
Well being technology field	- Establishment of university education and research in clinical and medical engineering in the late 1960s and during the 1970s - Development of university education and research - By end of 1980s the symbolic system had advanced and started to diffuse - First well being technology firms formed during the 1970s	- Early innovations targeted to specific user groups - Artifacts to emerge that probed further innovative work - Technological advancements imposing pressures on the health care field - Increasing concerns about productivity in the health care sector – incentives for opening up markets in the sector - Emergence of research groups in the area of self-management care	- Government driven institutional entrepreneurship - In 1995 a government program that outlined an information society strategy for Finland was presented - Cluster model idea spread among central Finnish industrial and policy actors - Emergence of activities to develop practices of data transfer in the health care system and in supporting an adaptive shift from paper-based patent data handling to digital patient data management	- The first technology program sparked an abundance of activities in technology development and trials to integrate new technologies into the health care sector - New technologies challenging the existing organizational and inter-organizational routines of actors in the health care sector during consecutive programs - Challenges in taking up new technologies in the sector to appear in several ways - During the second program innovation logics around well-being technologies developed - Rather autonomous well-being technology solutions and services developed during second phase

Table 4-1 Cross-case summary table on stages of emergence of technological fields

The cultivation and early innovation phase includes elements of both cultivation and early innovation. Cultivation in parts forms the inception of a novel field and includes science, research, and technical advancement paving the way for pressures to establish university education and/or research. It is important to note that though the novel field later emerges from these developments at universities and the establishment of research activities, it rarely does so in a direct sense but more often builds upon the knowledge base developed within these institutions, as it did in the functional foods field and the well-being technology field. It is these knowledge structures that facilitate initial learning, development, and cultivation of the symbolic system. During this phase these structures often formalize as boundary infrastructure, and through development of routines and the relational system between research and industry in connection with prevalent technological field. In this way this boundary infrastructures in a later stage impede the development of the actual novel technological field with its distinct carriers. This effect can be observed with the impeded emergence of the functional foods field due to the embedded and entrenched routines and social system between the food industry and public research organizations. Depending on the technology addressed, the formation of government agencies to address matters related to the subsequent emergent technological field seems to be mostly related to this cultivation phase. Together these developments contribute to the growth of a technological community and human capital around the emergent field. The other central property in this phase is the development of early innovations. Entrepreneurial and initial innovative activities start in this phase to emerge, and small scale production is established. In this way, the first technological archetypes of the novel technological field emerge. These materializations are typically presented, mimicking, and being interpreted through existing archetypes, such as the first functional food, Xylitol and the first larger use of steel in buildings when the house was fully covered with steel.

The early mobilization and structuration phase shifts the focus from non coordinated and non linked field developments to one driven by attempts to engage more actively organizations and actors in the development of the field but still not on a field wide level. This phase is driven by increasing and widening awareness about the emergent technology field opportunities. The cases show how this phase can be triggered by shifting strategies of incumbent firms, changes of market conditions of prevalent field, and early innovations entering the market. In this phase active mobilizing of local actors is starting to appear. These activities often expose different degrees of challenges with lack of industry interest and distrust among actors. Early structuration of the field takes place with the establishment and alignment of organizational routines among engaged actors. These developments also triggers advanced developments of the relational system. These activities together generate an increasing legitimacy of the emergent technological field and incentive for field level mobilization.

In comparison with the early mobilization and structuration phase, the field level mobilization phase is marked by processes of field level probing, matching of interest, and visioning. This phase manifests the emergence of institutional entrepreneurship. The cases show how this stage may vary largely in duration in response to the degree of contestation of institutional entrepreneurial activities. This stage is also influential in terms of directing and patterning the subsequent phase of field-level structuration. Based on the case studies it seems that the setup and quality of probing, matching of interest, and visioning together importantly influence subsequent dynamics of the structuration stage.

The field structuration phase then marks the phase of intensified concurrent development of institutional carriers. This field wide structuration varies in degrees paced by the interaction between individuals and organizations that the emergent field activities and mobilization triggers. It is at this stage with the concurrent development of institutional carriers and the technology becoming increasingly visible and perceptible through developments of artifacts that institutional contradictions emerge in a more substantial way. These contradictions are important in directing further development and structuration of organizational and inter-organizational routines. This phase is also marked and centrally influenced by processes of adaptation and structuration of firm strategies to the emergent technology-specific logics and innovation logics. Together these elements contribute to the emergent properties of field level structuration.

Stages of technology fields emergence	Properties and socio-cognitive dynamics
Cultivation and early innovation phase	*Cultivation* - Science, research, and technical advancement paving the way for pressures to establish university education and/or research - Establishment of university education that the novel field later emerges from/builds upon - Establishment of research in the area - Establishment of government agencies to address matters related to the subsequent emergent technological field - Learning, development, and cultivation of the symbolic system - Formation and institutionalization of boundary infrastructure - Growth of technological community and human capital - Formalization of routines and relational system between research and industry around existing technological field
	Early innovation - Entrepreneurial and initial innovative activities emerging - Small scale production established - First technological archetypes of the novel technological field emerge, mimicking or being interpreted through existing archetypes
Early mobilization and structuration phase	*Mobilization* - Active mobilizing of local actors - Different degrees of challenges with lack of industry interest and distrust among actors - Shifting strategies of incumbent firms - Increasing and widening awareness about emergent technology field opportunities
	Structuring - Increasing legitimacy of the emergent technological field - Changes of market conditions of prevalent field - Advanced developments of the relational system - Establishment and alignment of organizational routines - Early innovations enter the market and manifest the technological artifacts as an institutional carrier of the emerging field
Field level mobilization phase	- Processes of field level probing, matching of interest, and visioning - Emergence of institutional entrepreneurship - Large variety in times of this stage related to degree of contestation of institutional entrepreneurial activities - Direction and patterning of the subsequent phase of field-level structuration centrally influenced by the setup and quality of probing, matching of interest, and visioning
Field structuration phase	- Concurrent development of institutional carriers - Various degrees of structuration of field through interaction between individuals and organizations - Emergence of institutional contradictions - Increasing activities for developing technological artifacts - Technology becomes increasingly visible and perceptible - Development of organizational and inter-organizational routines - Adaptation and structuration of firm strategies to the emergent technology-specific logics and innovation logics

Table 4-2 Stages of emergence of technological fields and developments of institutional carriers

4.5.2. Development of institutional carriers in emerging technological fields

This section makes a cross-case analysis on development of institutional carriers of the four technological fields studied. Due to the apparent influence of the field mobilization phase in directing field level structuration, comparison between the stage of development of institutional carriers at the inception of field mobilization phase and subsequent development of institutional carriers is undertaken here. To illuminate how the field level structuration and concurrent development of institutional carriers is related to the field mobilization phase, the challenges arising in relation to development of carriers of the emergent field are summarized for each case. These three perspectives on development of institutional carriers in the four cases are summarized in Table 4-2.

In respect to the stage of development of institutional carriers at the inception of the field level mobilization phase, the cases differ with regards to how far the carriers had developed and how diffused the engagement had developed in regards to those that came to be involved in field structuration. While the community of engineers in modular constructional steel had increasingly started to engage already during the early field mobilization and structuration phase in later 1980s and the early 1990s, it was mostly researchers in the emergent well-being technology field and a small group of researchers in electronic publishing and printing that were engaged in developing technological artifacts and elements of the symbolic system. The emergence of the functional foods field and the developments of the symbolic system were largely driven by researchers that increasingly had started to engage in international collaboration and research within the scope of functional foods, while the industry was embracing and drawing on the carriers of the current product centered logic. The four cases reveal how field level mobilization centrally emerges from actors that are cultivated in the field and that become increasingly engaged in the development of the symbolic system.

During the phase of field structuration, developments of institutional carriers followed several evolutionary paths. The cases exhibit how this phase may involve (1) concurrent development of all four elements of institutional carriers of a technological field, (2) stepwise development of carriers, but also (3) non aligned and fragmented development of carriers. Equally the cases show how field structuration imposes adjustments, search for productive development of institutional carriers, and a gradual increase of intensity in development and co-alignment of emergent carriers of a field. Also to note is the importance of activities and properties of carriers of the emergent field that maintain and support the structuration process itself. While the functional food field was supported and legitimized in part by the materialization of the first functional foods in mid 1990s and the increasingly connected researcher community, electronic publishing and printing lacked these developments in the technological artifacts and the relational system which influenced subsequent reluctance for continuing with a subsequent collaborative program. This indicates that progress and development of institutional carriers in the studied cases importantly fed and upheld further interest and engagement in field structuration. Inability to progress in the development of institutional carriers during field structuration thus adversely affected the ability of institutional entrepreneurial action to further enable field structuration with the chosen focus and targeted actors. To then further activate field level structuration required refocusing and drawing on a reworked compilation of community of actors and related emergent institutional carriers. This refocusing can be observed in the well-being technology field with the reframing of each of the programs. Also in electronic publishing and printing a refocusing took place, but in this case the time to refocus required three years until a renewed field level mobilization phase set in.

Finally attending to how the stage of development of institutional carriers at the inception of field mobilization influence the structuration phase, is important for explaining pace of emergence of technological fields. The cross-case analysis shows how institutional contradictions emerged at some level during field structuration in each case. Depending on how developed and wide spread the cultivation and early structuration were and how intense the development of institutional carriers had been, influenced how strongly institutional contradictions emerged and how easily they could be settled. In modular constructional steel the construction firms were skeptical about larger scale use of steel. This skepticism was overcome during the program already in part because of the rather far advanced developments of institutional carriers of the field and in part as a result of the momentum received through the intricate and successful strategizing around field level structuration. On the contrary, the emergent well-being technology field experienced strong institutional contradictions, in part as it challenged each carrier of the dominant public health-care field and in part due to the inability to identify and undertake institutional embedding measures to advance field wide development of normative and cultural-cognitive elements of the emergent field. The structuration challenges in the well-being technology field also illustrate how one or two carrier may become bottle necks for the emergence of a technological field. In the fields of electronic publishing and printing, well-being technology, and functional foods the challenge in enabling standards to develop and diffuse, impeded the overall productivity of field structuration.

	Field mobilization phase: Stage of development of institutional carriers	Field structuration phase: Developments of institutional carriers	Challenges arising from emergent stage of institutional carriers
Modular constructional steel	- Endogenous and emergent collaborative developments (both public research organizations and industry) of symbolic system, relational system, and routines	- Field wide engagement in co-evolutionary development of symbolic system, relational system, routines, and technological artifacts. - Steel in constructions gaining symbolic value	- Necessity to actively uphold the rationale for engagement in field wide structuration. - Emergent technological field challenging prevalent technological artifact (concrete)
Functional foods technology field	- Institutionalized symbolic system (values and classifications) around health related aspects of food, products, and process related research - Relational system and routines developed among researchers	- Stepwise development of carriers. - Step I: Intense development of symbolic system through laws targeting technology use and values related to functional foods. Development of technological artifacts (science driven). - Step II: Development of relational system and routines (innovation driven)	- Matching of emergent technological artifact and in part established evaluation routines and problem solving strategies (researchers) and in part emergent (industry and end customers) symbolic system to enable development of productive relational system and routines - Different technology specific logics and innovation logics enacted by separate legislative bodies of two Ministries
Electronic publishing and printing field	- The symbolic system by printer technology community penetrating both paper and graphic arts industry - Initial developments of elements of the relational system around the emergent field within graphic arts industry - Incentives for responding to emergent digitalization of media	- Scattered developments of organizational and inter-organizational routines, and the relational system within and between paper industry and graphic arts industry in Finland - Transition and development of symbolic system and artifacts around the emergent field of electronic publishing and printing centrally in interaction with international printer manufacturers and ink-producers	- Inability to develop routines and productive relational system due to uneven internalization of symbolic system and contact with technological artifacts between researchers and industry - Lack of exemplars to provide symbolic value - Inability to support emergence of standards and classification
Well-being technology field	- Values and expectations (symbolic system) about well-being technologies developed among a rather small group of researchers - Law allowing public procurement in health care established	- Step wise increased alignment and development through consecutive programs of the symbolic structure, technological artifacts, and the relational system - Piloting and materialization of technical artifacts and symbolic system during programs, directing scope and actions - Development of social capital among central stakeholders during second program	- The emergent well-being technology field challenging substantially each institutional carrier of the public health care structure - Inability to identify and undertake institutional embedding measures to advance field wide development of normative and cultural-cognitive elements of carriers

4-3 A synthesis of development of institutional carriers and related challenges in four emerging technological fields

4.5.3. Shifting logics of technology fields and arising contradictions

This final section of the cross-case analysis considers similarities and differences in the shifting logics of technological fields and arising contradictions, to unravel underlying socio-cognitive explanations. In each case the emergent field imposes shifts in both technology-specific logics and innovation logics. The shift in innovation logics that the four cases exhibit in part reflects more general shifts in focus of technology and innovation policy during the studied period, such as the increasing focus on the systems of innovation approach and inter-organizational collaboration in innovation. This said, these shifts in innovation logics can be said to be equally tied to the distinct properties of the emergent technology as well as the arising challenges in relation to creation of relational structures and the commercialization around the emergent technological fields.

Especially the intensified use of information and communication technologies was an underlying element in the emergence of the well-being technology field, electronic publishing and printing, and the modular constructional steel. Thus the shift in technology-specific logics for each of the three cases includes increasing linkages in the business and production value chain and standardization of these interfaces. Shift in technology specific logics imposes changes of prevalent value propositions. The more distant the connection between the prevalent and novel technology-specific logic was presented, the more challenging it was to gain legitimacy for the emergent logic. The imposed change from a product focused food manufacturing to one incorporating ingredients was challenging as functional foods were compared to medicines, which fundamental challenged the traditional idea of foods, specifically regarding institutionalized values and symbolic meanings of food by end producers and the novel role of producers as manufacturers of ingredients for other producers. Again, steel as a construction material was in part related to shift from one material to another in construction work, and in part related to the visual appearance of buildings for the public and customers, which is more a cultural and fashion type dimensions than a fundamentally underlying institutionalized property of the functioning and role of buildings.

With regards to enabling properties for solving institutional contradictions the cases illustrate how both research and industry may function as institutional entrepreneurs. This said, they draw on distinct strategies and in this regard varying abilities to tackle and mitigate emergent contradictions. In both the field of electronic publishing and printing and the well-being technology field researchers were central in educating actors within the emergent field, while industry proactively created objects to persuade the value of the novel technology in the field of modular constructional steel. While awareness raising activities by researchers in the emergent field of functional food and well-being technology was productive within the research community, they were less successful in with regards to their advocacy and field level visioning and probing among industry actors. In this way, at a more general level the cases shows how capability of institutional entrepreneurial action was facilitated by the width of legitimacy they respectively had developed in the targeted community of industry, research, and government actors around the emergent field.

	Shift in technology-specific logic	Shift in innovation specific logic	Enabling and constraining properties for solving institutional contradictions
Modular constructional steel	- Shift from traditional constructional steel (intense craftsmanship) as a supportive material to an integral part of constructions. Larger scale use and the material more visible in constructions - Shift in interaction and communication between firms within the construction value chain from a one way process to a chained process	- Shift from a project based culture (moderate levels of R&D activities) to a coordinated and collaborative system-level innovation culture	- Steel to be associated with modern technology and growth enabled shift: Boom of the information and communications industry and rapid growth period in constructional works in Finland - Strong leadership and the powerful position of Rautaruukki enabling shift in innovation and technology-specific logic - Sector-level strategy development work and active and frequent mobilizing enabling shift
Functional foods technology field	- From foods to ingredients as product - Change in value proposition in relation to foods towards end customers. Food manufacturers as a new category of customers	- From short term product development to science-driven innovation logics - From national to international researcher community collaboration	- Active research community enabling shift but at the same time legitimacy constraints of researchers impeding shift. - Emergence of exemplars/artifacts legitimated the shift - Legislative developments and new laws at the national level enabling shift but struggle in legitimizing functional foods in EU impeding industry wide shift
Electronic publishing and printing field	- Shift of institutional carriers of the predominant publishing field towards digitalization, and the resultant contestations of paper as carrier and interface between the two industries - From a paper based business logics of graphic arts industry to one with linkages between paper and digital content: on-demand printing and low cost tailoring of content	- From innovation in materials, processes, and print techniques to technological and organizational system innovations	- Substantial ambiguities in relation to the technological shift - Institutional entrepreneurship for emergent technology-specific logics of electronic publishing and printing by researchers - Lack of the legitimacy and weakly embedded relational structures of institutional entrepreneurial actors - Unequal commitment and divergent interests by the paper industry and graphic arts industry constraining shift
Well being technology field	- Public health care dominated logic towards a well-being technology field-embracing logic - Institution based care model to a self-management logic - Coordination needs in service delivery value chain - Increasing autonomy of health care providers (hospital districts and municipalities)	- From product related innovation logics to system innovations logics - Lack of data standards and procedures for data security resulting in firms developing autonomous solutions and services	- Advocacy by researchers and educating stakeholders facilitating field emergence - Technology programs materializing institutional contradictions between the fields, supporting subsequent planning and coordination in the field - Divergence in technology-specific logics and innovation logics imposed by stakeholders impeding agreement regarding path and change in the health care sector - Lagged development of standards and regulation constraining development of the field

Table 4-4 Character and properties of shifting logics with emerging technological fields

5. MACRO-LEVEL FOUNDATIONS OF EMERGING TECHNOLOGICAL FIELDS

Building on insights and observations from the four cases, the cross-case analysis, and the extant literature on awareness, institutional entrepreneurship and institutional contradictions, propositions regarding the macro-level emergent properties in the development of novel technological fields are outlined in this chapter. Specifically, the chapter aims at building explanations and theory for macro-level emergent properties and the causal links found when comparing the cases and previous research, and theorization on the focal phenomena. In this regard the thesis follows the processes of theory building from case studies (Eisenhardt, 1989). Categories and dimensions that were closely examined between the cases followed the guiding framework developed in chapter 2 and the subsequent emergent dynamics in the case analysis described in chapter 4; specifically attending to awareness, institutional entrepreneurship, and institutional contradictions. A comparison with the extant literature is carried out to in order bring forward both supportive findings and theoretical arguments for developing propositions, but equally to provide contrast and identify conflicting explanations. Bringing out conflicting explanations strengthens internal validity and addresses the contextual and distinctiveness of socio-cognitive dynamics and emergence at the macro-level in technological fields in relation to other types of fields.

5.1. Stages of technology field emergence

Recent studies on the emergence of institutional fields have highlighted the role of collaboration as a source and enabler of institutional change and emergence of 'proto-institutions'(Lawrence et al., 2002). Proto-institutions are described as including new *"practices, technologies, and rules that are narrowly diffused and only weakly entrenched, but that have the potential to become widely institutionalized"* (Lawrence et al., 2002:283). These practices, technologies, and rules transcend and arise within collaborative relationships, which provides a central social mechanism for institutional change (Lawrence et al., 2002). Inter-organizational collaborative structures produce innovations and as they start diffusing can gain institutional properties. Lawrence et al. (2002) more generally address the collaborative structures as social mechanisms and how specific characteristics of collaboration, such as embeddedness and involvement, influence productive emergence of proto-institutions. The empirical study reported in this thesis further enriches this by; (1) considering both social and cognitive processes, (2) exploring how these two are coupled, and (3) by considering how socio-cognitive mechanisms influences structuration and emergence of new fields.

The case analysis provides support for distinguishing four stages in technology field emergence; a cultivation and early innovation phase, an early mobilization and structuration phase, a field level mobilization phase, and a structuration phase. Taken together the four phases address the *gradual emergence* of 'proto-institutions' (Lawrence et al., 2002) which arises by addressing micro- and macro-level socio-cognitive mechanisms. In this respect this thesis considers the socio-cognitive mechanisms that, in important ways, emerge and take on different pronunciations in the three phases. This has implications for the progress of emerging technological fields and how any of the previous stages influences the following phase through the prevailing socio-cognitive dynamics and available resources that institutional carriers can draw upon. These dynamics impact how institutional entrepreneurship, awareness, and contradictions emerge around novel technological fields.

The four case studies and the cross-case analysis provide evidence on the interactions between micro- and macro-level emergent socio-cognitive properties and how these dynamics provide the specific characteristics of emergence in each phase. Framing the analysis this way provides a deeper understanding of emergence during the cultivation and early innovation phase, and how socio-cognitive dynamics play out, and develop and influence subsequent early mobilization and structuration, and field-level mobilization. The emergent property of field-level mobilization and the stage of development and completeness of institutional carriers, together influence the subsequent emergent properties of structuration. This suggests that each phase provide avenues to the next emergent phase in important ways. Depending on how, by whom, and in what stage of field emergence actors are mobilized, the field will take on distinct emergence and socio-cognitive dynamics. To conclude, it is the emergent properties of socio-cognitive dynamics that then direct, pattern, and pace the emergence of technological fields. In the following initial propositions for field level socio-cognitive dynamics for each identified phase in emergence of technological fields are outlined.

The cultivation and early innovation phase marks a beginning of a novel field through developments of a symbolic system. Although successful field level mobilization began in mid 1990s in all four studied fields, education and initial research in the fields started thirty years earlier during mid 1960s. During the cultivation and early innovation phase initial codification and categorization developed that later in the field mobilization phase and in the structuration phase was drawn on and built upon.Cultivation of a novel symbolic system thus gradually diffused in concert with developments of classifications, standards, and regulations of the field. Individuals that were educated in the new domain, and those that actively participated in developing university curricula and initial research practices at university laboratories and research institutes within the emerging field, appeared to be particularly critical for enabling and directing activities during this phase. Later, these initially active individuals also came to hold influential roles in facilitating transitions to field level mobilization and transition to structuration.

The development of the symbolic system intensified communication between individuals. The cultivation and early innovation phase thus supported the establishment of a common language that increasingly become available for each of the dispersed actors to draw on and reflect from their distinct location. A symbolic system promotes uniformity and consistency of action across different actors (Scott, 2008). At the same time, the symbolic system represents a system of knowledge, beliefs, and 'moral authority' (Scott, 2008:12)[43]. Knowledge and know-how in the emerging technological field facilitated and sparked initial innovation activities and entrepreneurial firms to develop in the field. The development of innovation and technological artifacts provided the initial attention and made the initial appearances of the novel field available for larger audiences to reflect upon. On the other hand, these initial innovations offered distinct technology frames for interpreting the field, which made other properties of the emergent knowledge structure less visible (Bijker, 1987). This created interpretive flexibility (Pinch et al., 1987) around the emerging technological field. With technological artifacts and technological frames imposed, several groups of actors, such as architects, engineers, steel manufacturers, construction firms, and users, could engage in interpretation of the technological artifact. During this phase, action was more ad-hoc based and non-coordinated in relation to the later stages.

The four cases indicate that productivity of field-level mobilization and structuration importantly depends upon the degree of diffusion and development of the symbolic system. Although the symbolic system for well-being technologies started to develop during late 1960s, it was only during the early and mid 1990s early mobilization and structuration phase that this symbolic system started to increasingly gain shape and to increasingly diffuse. The different logics that actors held for interpreting and establishing the symbolic system resulted in conflicting symbolic systems on which to draw. This was reflected in the challenges in the mobilization and field-level structuration activities and thus resulting in institutional contradictions. In the modular steel construction field the symbolic system had similarly already widely diffused during the 1970s and 1980s, which provided a common language and coherent symbolic structure to enable subsequent field-level mobilization and structuration, and

[43] These ideas were originally presented by Durkheim.

digitalization of the existing symbolic system. In the electronic publishing and printing field, the symbolic system had already started to develop in the 1970s with research in media technologies. But only with the first commercial digital printing press machines in 1993 did the symbolic structure for electronic publishing and printing start to develop intensively in Finland. These externally provided exemplars (Van den Belt et al., 1987) and imposed technological frames (Bijker, 1987) enabled field mobilization and structuration in electronic publishing and printing. As the symbolic structure had not spread widely and the imposed technological frame was variously addressed, mobilization and structuration faced extensive contradictions that, only in 2005 with a second attempt of field-level mobilization, gained the traction for furthering productive field structuration. These different dynamics between the cases show how a less developed symbolic system inhibits productive field mobilization and structuration.

Similar findings have been reported in social psychology relating to social categories and schemas. Fiske and Taylor (1991:131) have concluded that *"the effects of schemas on memory are strongest when the schema is present from the beginning, as many social schemas are, being cued by customary labels and physical features"*. This would imply that when schemata,[44] or symbolic structures of an emerging technological field, are less well established, it is the dominant technology specific logics and innovation logics that actors drawn upon. This results in constrained and institutionally inhibited learning and innovation around the emerging technological field. As the symbolic system is diffused more widely, it provides necessary coherence and stability in sense-making in order to advance the establishment of dominant designs and technological trajectories (Abernathy et al., 1978; Dosi, 1982; Porac, Rosa, Spanjol, & Saxon, 2001). This suggests that:

> **Proposition 1: Wide-range diffusion of symbolic systems positively influences the success of the mobilization and structuration of emerging technological fields.**

The presence of technological artifacts provides meaning to and understanding of the emergent opportunities (Suchman, 1995). Interpretations can, to this extent, more productively reflect on the technological artifacts that arise through the developed symbolic structure. Development of initial innovations function as the exemplars (Van den Belt et al., 1987) and anchors for other actors which are important in directing attention and supporting the development of designs around an emerging technological field. The commercialization of Benecol and the escalating success of Xylitol in the late 1990s provided exemplars for the functional foods field, with

[44] A schema is defined as *"a cognitive structure that represents knowledge about a concept or type of stimuli, including its attributes and relations among those attributes"* (Fiske & Taylor, 1991:98).

increasing attention from public media, funding agencies, and company leaders to the emerging field. Artifacts and representations of the novel technological field also function as a central mechanism for delegitimizing the existing institutionalized carriers of the predominant fields. The lack of technological artifacts in the emerging field of electronic publishing and printing in Finland during mobilization and early structuration stifled the emergent processes and caused ambiguity for participants. On the other hand, the increasing pool of high-tech offices built during latter half of 1990s, using steel as a central and visible material, increased both national and international legitimacy of the technology and the Finnish steel constructional field.

Meyer and Rowan (1977) have argued for two antecedents to legitimacy, one being technical efficiency and the other being conformity to institutional myths. In this respect, the presence and materialization of technological artifacts provides and provokes alternatives to the prevailing technology-specific logics when they are objectified and shown to have greater efficiency than the prevalent technology. From this perspective, new technologies, when they are demonstrated, are not easily denied and have the potential to delegitimize existing technological artifacts and related institutional carriers around them. In addition, the artifacts verify the existence of knowledge and resources to create technologies within the emerging technological field. This suggests that technological artifacts provide a critical element for the deinstitutionalization of the cultural-cognitive properties residing within the predominant technology-specific logic. In their study on Edison's system of lighting and the shift from gas and arc lighting to electric lighting, Hargadon & Douglas (2001) explain how for a novel technology to enter existing technological structures, requires elements of newness and that the new technology was identifiable with the existing technology specific logic. Innovation within a novel technological field then enables the habitualization of technological artifacts. The rather few adopters in this phase, the implementation of the symbolic system, vary considerably and have been described as a pro-institutionalization stage (Tolbert & Zucker, 1996). Habitualization thus facilitates the emergence of practices and *"patterned problem-solving behaviors and the association of such behaviors with particular stimuli"* around the novel symbolic system and provides the path to objectification (Tolbert et al., 1996:181). This suggests that:

> **Proposition 2: The abundant presence of technological artifacts representing the novel technological field positively affects the legitimacy of field-level mobilization and structuration.**

In the mobilization phase, the emergence of technological fields was increasingly driven by the interest and awareness of distinct set or group of actors. In this phase institutional entrepreneur's sought support and resources for field-level structuring and coordination. During the phase, the legitimacy of institutional entrepreneurship was reflected in the institutional contradictions that arise and the subsequent effectiveness of institutional entrepreneurial actions.

Legitimacy for engaging in institutional entrepreneurial action is related to the power of actors in an inter-organizational field that arises through formal authority, scarce or critical resources, and discursive legitimacy (Hardy & Phillips, 1998). While formal authority addresses recognized and legitimated rights of organizations or group, scarce or critical resources addresses the role of resource dependencies of organizations. Discursive legitimacy refers to actors that hold legitimacy with regard to *"speaking legitimately for issues and of organizations affected by the domain"* (Hardy et al., 1998:219).

In the emerging modular steel construction field, the firm Rautaruukki controlled scarce and critical resources from a near monopoly position of steel production in Finland. This provided the firm with wide-range legitimacy to enable mobilization and field-level structuration. Equally, embeddedness and social skills of the director at Rautaruukki, who later acted as director at the research institute VTT, provided discursive legitimacy for initiating field-level mobilization and structuration activities. Developments in research in functional foods, which originated from larger corporate research laboratories and strengthened research orientation by public research organizations from previous industrial applied research, directed research directors at firms and in public research organizations to push field-level mobilization and structuration in functional foods. To this extent field-level mobilization was not strongly linked to the top management in firms and equally had not been actively embraced in corporate strategies. As the existing technology-specific and innovation logics prevailed, organizational and inter-organizational routines, and the relational system around the emerging technological fields, was constrained and needed to adapt and develop in parallel. This indicates how contradictions in technology-specific logics also emerge from shifts in innovation logics. Legitimacy for field-level mobilization and structuration was thus limited. This impeded the development and facilitation of productive socio-cognitive dynamics, and restrained development of relational structures and organizational and inter-organizational routines.

Field mobilization in electronic publishing and printing took place at the intersection between the paper industry and graphic arts industry. The intersection refers here to the overlapping technological fields of paper and graphic arts, which relied on distinct technology specific logics and innovation logics. Field mobilization was enabled by the paper industry and a small number of researchers in electronic publishing and printing. The research director from the paper industry lacked wide-ranging legitimacy in the graphic arts industry in order for field mobilization in electronic publishing and printing to take place. Those researchers that were cultivated in the emerging field of electronic publishing and printing struggled due to the lack of legitimacy with regards to the emergent technology specific logics in the graphic arts industry. This suggests that institutional work, such as theorizing and pushing for changes in normative associations (Lawrence et al., 2006), were not able to attain wide-range discursive legitimacy. With insufficient field-wide legitimacy and insufficient abstraction and complexity of theorization, diffusion is hampered by ambiguities in communication between theorists and adopters and stakeholders around an institutional field (Strang et al., 1993). In electronic publishing and printing, legitimacy and theorization was constrained due to entrenchment of predominant technology-specific institutional carriers and ambiguities about the shift. These findings indicate that:

> **Proposition 3: Wide-range legitimacy of field-level mobilization positively affects the productive structuration of an emerging technological field.**

5.2. Awareness and emergence of technological fields

With the emergence of a symbolic system in a novel technological field, awareness about opportunities develops. Four distinct elements of what constitutes awareness around novel technological fields emerge from the case analysis. Awareness in emerging technological fields include consciousness and understanding about: (1) the potential of new technology; (2) the need for change of predominant technological field; (3) the vision for how things should and could be changed to facilitate better operation; and (4) frustrations or disappointment with existing technology field solutions. While awareness seems to be linked to institutional entrepreneurship in the early phase of an emerging technological field, at the same time it develops and diffuses through actors becoming engaged and involved.

Awareness of the potential of new technology addresses an understanding of the value of new technologies and how these could be used and how existing technologies could be improved. Awareness is gradually established among those involved and engaged in the development and cultivation of an emerging technological field. In both the electronic publishing and printing field and modular constructional steel field, it was those involved in the early university courses and programs that became active in initiating field-level mobilization and who were highly engaged in the field-level structuration stage. But field mobilization only occurred 10-20 years from the initial activities in the cultivation and early innovation phase. This indicates that awareness builds up through actors’ long-term enactment, in parallel with initial innovation activities and developments of technological knowledge in the field. Awareness of needs for change of predominant technological fields therefore forms through, insights of required technology development, technology diffusion, collaboration, and the changes needed in institutional arrangements.

Awareness in an emerging technological field included having vision. The modular constructional steel case illustrates how an understanding of how things should and could be changed to better facilitate operation was elaborated during the program. Formation of the relational system and how to arrange organizational and inter-organizational routines within the emerging field was carefully studied and discussed in field-level strategy projects. This visioning was important to recognizing what technologies should be developed, by whom, and how. It included comprehension of how collaborations should be improved; which institutional arrangements, standards, and educations should be in place to improve things. This work was central to advancing field-wide awareness in the modular constructional steel case.

Frustration or disappointment with existing solutions reflects a realisation of the obsolescence of current technologies, working patterns, and institutional arrangements. During the early 1990s, with the increasing penetration of information and communication technologies and increasing cost of health care sector, disappointment and frustration had started to rise. Frustration and disappointment then increased with the failure of the first national technology program in the health care sector. It was only when this frustration diffused more widely among all stakeholders that awareness about required change started to become clear. These challenges seem to increase awareness through the identification of bottlenecks that hinders effective operation and value creation. Awareness thus increases the identification of technological gaps that makes certain important activities or functions impossible and therefore requires other paths.

There are only few studies that have specifically considered several carriers and their related developments and impact on the unfolding of emergence of fields. Davis and Greve (1997) have showed how different carriers and structures of cultural systems importantly influenced diffusion of new corporate governance schemes, focusing on golden parachutes[45] and poison

[45] "Golden parachutes are contracts that award generous severance packages (typically three years' salary) to top executives whose employment ends following a takeover" (Davis & Greve, 1997:2)

pills[46]. While golden parachutes diffused through geographic proximity of firms, poison pills schemes spread through national elite networks (Davis et al., 1997). Garud et al. (2003), explored developments of the wind turbine industry in Denmark and U.S.. The success of the emergence of the Danish wind turbine industry is partly explained as the result of a process of bricolage, were inputs from distributed actors and their gradual embeddedness in the emerging field resulted in *"accumulating artefacts, tools, practices, rules and knowledge"* (Garud et al., 2003:294) that aligned and enabled productive structuration. Simultaneous structuring of technological artefacts in conjunction with a coherent and shared conceptual system creates *"products that can be described, valued, and exchanged"* (Porac et al., 2001:241).

The four fields analyzed show how the increase and diffusion of awareness is related to the synergistic developments of institutional carriers. The fragmented interaction between the two industries in electronic publishing and printing and between research and industry during field-level mobilization and field structuration did not productively facilitate awareness. While researchers that dominated the field mobilization and structuration phases in functional foods influenced developments of the symbolic system and technological artefacts, less attention was given to the development of the relational system and organizational and inter-organizational routines. In the modular steel construction field, all four elements of institutional carriers were developed synchronically and intensively during the field-level mobilization and structuration phases resembling a process of bricolage. This was critical for advancing field-wide awareness among participants. This suggests that:

> **Proposition 4: Lack of synergistic development of the institutional carriers of technological fields, including technological artifacts, symbolic system, relational structure, and practices, constrains the advancement of field-wide awareness in novel technological fields.**

Although synergistic development addresses the value of alignment, enactment, interaction, and coordination, it does not explain the underlying socio-cognitive mechanisms and how they interact with emerging institutional carriers in a field. In their study of Edison and the electric lighting system Hargadon & Douglas (2001) attended to the importance of presenting the newness of an invention in order to draw attention, and simultaneously presenting the new technology as familiar to existing technology specific logic. This means that for successful

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[46] "Poison pills are securities that prohibitively raise the cost of hostile takeovers (those made without gaining the approval of the target's board of directors) by giving target shareholders the right to buy shares at a 50% discount if an acquirer passes a certain ownership threshold" (Davis & Greve, 1997:2)

diffusion, new technologies and their properties should be presented *"in the language of existing institutions"* (Hargadon et al., 2001:478). Hargadon & Douglas (2001) address the value from 'robust design strategies' when introducing radical technological change in an existing technological structure. Similar arguments have been put forward by Leblebici et al. (1991:333) in their study of the U.S. radio broadcasting industry where they found that analogies where influential endogenous mechanisms. Analogies facilitated sense-making and management of the new phenomena during institutional change. Together the two studies attend to the embeddedness of the symbolic system and technological artifacts in routines and practices within a technological field and mechanisms that facilitate institutional change. To this extent there are possibilities for being strategic in legitimizing the new technology by analogies and *"choosing designs that couch some features in the familiar, presents others as new, and keep still others hidden from view"* (Hargadon et al., 2001:480). This said, it is also important to retain flexibility for the development of the use and understanding about the new technology. This has been highlighted by scholars in the social construction of technology field. Wide acceptance and closure around a technological design that is emerging, is often preceded by a phase of interpretive flexibility (Pinch et al., 1987). Interpretive flexibility refers to the flexibility of design and interpretation that takes into consideration actors cultural and historical background which seems to critical in enabling legitimacy for the wide-scale diffusion of technologies (Pinch et al., 1987).

Field-level mobilization and structuration of the modular constructional steel technology field widely engaged both industry and research actors. Engineering firms, software developers, customers, and manufacturers became actively involved during the structuration phase. A contrary position in electronic publishing and printing is that mobilization and structuration was fragmented and forced in response to developments of digital printing press machines. In this respect interpretive flexibility was too fragmented to productively come to a closure, and enable productive innovations and structuration of the field. Also, institutional work of theorizing, educating, defining, and changing normative associations (Lawrence et al., 2006) was not aligned towards actively bridging the two industries through institutional embedding. In the well-being technology field, the different stakeholders struggled over the emergent technology-specific logic and innovation logics. Little embeddedness of emergent institutional carriers was carried out during the initial stage of field-level mobilization and structuring. Only with increasingly appearing institutional contradictions and failures in facilitating field structuration, did the different stakeholders gradually start to appreciate and approach each other and considered and took into account the respective prevailing institutional properties. In the functional foods field, the domination of a research logic during the 1990s, inhibited the subsequent focus on commercialization due to existing institutionalized practices following this early phase logic and existing linkages to the different institutional carriers of the field. This suggests that:

> **Proposition 5: The institutional embeddedness of carriers of an emerging technological field, including technological artifacts, symbolic system, relational structure, and practices, positively affects the formation of field-wide awareness towards the emerging field.**

5.3. Institutional entrepreneurship and emergence of technological fields

The case analysis provides an in-depth analysis of the socio-cognitive mechanisms related to institutional entrepreneurship, awareness, and the resultant institutional contradictions in emerging technological fields. This section develops propositions on institutional entrepreneurships and emergence specifically attending to macro mechanisms and micro to macro mechanisms of emergence of technological fields. Towards this end, the empirical study addresses how specific properties of institutional entrepreneurship influence field-level emergent properties.

The case analysis demonstrate how individual actors, networks of actors, and organizations may each function as institutional entrepreneurs in emerging technological fields. The study demonstrates how the role of institutional entrepreneurs varies with the developing field, and is more pronounced during specific phases. This indicates a temporality of institutional entrepreneurship during technology field emergence as a reaction to distinct phases and the stages of emergence of a field. It also suggests that institutional entrepreneurship transforms and can be taken up by other actors. This is important as these transitions may influence and change the emergent socio-cognitive dynamics in the field. This is more carefully addressed in chapter 6 where the focus is on individual-level traits that enable awareness, and how awareness is related to the visibility and legitimacy of institutional entrepreneurial activities in the field.

In modular constructional steel, several individuals were engaged in facilitating field-level mobilization and structuration. A director from a large steel producer importantly enabled productive field-level mobilization and structuration, but withdrew later following changed duties. Earlier, a researcher at VTT that had become engaged in standardization was central to facilitating the development of the symbolic system in the field. Then, during the structuration phase, this senior researcher came to hold a central role, a position he retained during a subsequent program. The functional foods technology field again was initiated by active researchers and research directors from large firms in the field. This said, the real impetus for collaboration in foods came much earlier from a government committee that proposed the initiation of a technology program in the food industry sector. Even though two attempts were subsequently made to start a program, the mobilization did not gain sufficient legitimacy from industry and research groups. Only with the changing market dynamics and increasing research in the functional foods field did the mobilization succeed.

In the well-being technology field, it was a research director at VTT and the government funding agency Tekes that engaged in institutional entrepreneurial activities and mobilization. As a fringe player in the health care sector, Tekes lacked the required legitimacy to align field-level activities with their program goals. Instead, Tekes imposed the technology-specific logics of increasingly introducing private enterprise solutions for the health care sector. During the Digital Media in Health Care program, structuration of the field was focused on system-level change and take-up of information and communication technologies in the health care sector. Although this program attracted telecommunication operators and system developers, the majority of stakeholders in health care, such as the Ministry of Social Affairs and Health, research institutes, and hospital districts were reluctant to engage actively and did not understand well enough the rationales of the agency and technology program activities. Tekes as an institutional entrepreneur in the well-being technology field thus lacked the necessary legitimacy to enable productive field-level mobilization and structuration. The initial challenges in facilitating and enabling structuration in the field during the first program, made Tekes engage in strategic field-level engagement by, for example, inviting the general director for the National Research and Development Center for Welfare and Health Stakes to become board member of Tekes, and by more carefully building interfaces between industrial and public policy makers through working groups and task forces.

When a third program in the health care field was initiated in 2004 the field was increasingly unanimous with regards to the proposed technology program strategy and the supportive activities that enabled field structuration were also in preparation. This indicates that legitimacy of institutional entrepreneurship increased with these strategic field-level engagements and the active participatory strategy taken by Tekes. This probing and initial field-level structuration during the first and second programs provided valuable feedback on the success and failures of the imposed innovation and technology specific logics. With increasing interaction between the stakeholders around well-being technologies the emergent field received more direct and distributed feedback compared to the previous indirect approach. This provided a fertile base for productively directing, engaging, and enabling collaborative research, technology development, and innovation activities and the structuration of the well-being technology field. This suggests that:

> **Proposition 6A: Wide-range legitimacy of institutional entrepreneurs has a positive effect on the productivity of field-level mobilization and structuration in emerging technological fields.**
>
> **Proposition 6B: Strategic field-level engagement and advocacy by institutional entrepreneurs has a positive effect on the productivity of field-level mobilization and structuration in emerging technological fields.**

5.4. Institutional contradictions and emergence of technological fields

This section addresses institutional contradictions and emergence of technological fields. Section 2.2.4 presented two central mechanisms that contribute to institutional contradictions: (1) a lack of legitimacy of the novel technological field and (2) incompatibilities between predominant technology-specific and innovation logics, and the emerging technological field logics. The case analysis show how new technologies challenge dominant technology-specific logics and innovation logics. New technologies not only enter existing fields through cultivation and early innovation activities, but also through disruptive technologies that attracts actors to theorize and explore the necessity to attend and engage with these new technologies and link them to already existing or emergent symbolic structures. The cases analyses suggest that emerging socio-cognitive dynamics and the emergence of technological fields is contingent upon who the new technology is attached to and how institutional change is theorized. Together these properties influence how institutional contradictions appear and how strong or weak they are perceived.

With the institutional work of theorization (Lawrence et al., 2006) of the well-being cluster, new technologies where imposed by the Ministry of Trade and Industry and Tekes as being relevant to the whole health care sector and the need for the sector to embrace such technologies. The initial strategy taken by Tekes to facilitate industry actors in creating novel technological systems in the health care sector encountered a multitude of challenges. The program strategy and approach did not match the logics of the Ministry of Social Affairs and Health, which was concerned with how to facilitate an information and communication technology system-level change, but without larger industry influence. These contradictions emanated from the division of responsibilities of the two sector ministries, the Ministry of Trade and Industry and the Ministry of Social Affairs and Health, and their rather different approach to the imposed and proclaimed control structures for the health care sector. While the Ministry of Social Affairs and Health imposed controlled adoption of information and communication technologies and was cautious of too strong a private sector involvement, institutional contradictions arose with regard to legitimacy claims that undermine functional inefficiencies and adaptation that undermines adaptability. The Ministry of Trade and Industry, on the other hand, together with Tekes imposed an industry driven and innovation-centered logic that was interpreted by stakeholders in the health care sector as lacking the necessary institutional embeddedness and thus created inter-institutional incompatibilities. The different field-level logics thus created institutional contradiction which impeded the initial productive mobilization and structuration of the field.

These contradictions are important for field emergence, as they reshape consciousness, which, in important ways, enables further new insights and interpretations to evolve, establish, and become accepted (Seo et al., 2002). Subsequently, new definitions and new approaches to well-being technologies developed in subsequent programs. This shows how the divergent interests in the area of well-being technologies co-evolved, and with the gradual convergence of the necessary institutional change in health care came to provide the necessary material and symbolic support for structuration of the field (Purdy et al., 2009)

In the electronic publishing and printing field, both the paper industry and the graphic arts industry were mainly concerned with facilitating developments of the predominant paper-based era of publishing and printing although digitalization simultaneously was opening up an avenue for a digitalized era for both industries. In addition, these industries embraced rather different innovation logics, paper industry being much more research oriented, while the graphic arts industry was only a user of technologies. Imposing interaction and integration of the two industries during this paradigmatic shift only increased ambiguities and contestations between the different logics. In modular steel construction, the community involved was rather small and were all attached to the construction industry. Although the largest firms had stronger capacities in research and development, the imposed innovation logics followed the principles of the familiar pragmatic project culture in the industry. Importantly, the Finnish Steel Construction Association had increasingly educated and engaged actors since the late 1980s and this supported convergence with respect to innovation logics and legitimacy for field-level mobilization and structuration with new technology-specific logics. The legitimacy of mobilization and structuration received by the modular constructional steel field arose from innovation and technology-specific logics that both emphasized the coordination among actors, the technology-specific logic based on information flow between relevant actors, and the innovation logics based on industry-wide collaboration that were analogical with the previous technology-specific logic (Hargadon et al., 2001). This suggests that:

> **Proposition 7: The legitimacy of mobilization and structuration of an emerging technological field is negatively affected by the diversity and inconsistent accounts of stakeholders with respect to predominant field-level logics and governance structure.**

The relationship between institutional contradictions and awareness is subtle, especially in relation to how they are related to institutional change. Although institutional contradictions constrain ongoing structuration, they also trigger awareness about the prevailing institutions through the reactions of actors embedded in these contexts concerning the emerging technological field. Awareness and institutional contradictions are both valuable and, to an extent, necessary for enabling productive field-level structuration and the emergence of productive micro- and macro-level socio-cognitive dynamics. But institutional isomorphic change does not require a high level of awareness as action is based on mimetic, coercive, and/or normative behavior (DiMaggio et al., 1983), and does not therefore depend on a substantial understanding and calculation of rational action. This suggests that institutional contradictions can be weaker or stronger with respect to whether institutional change encompasses isomorphic behavior or requires active reformulation of underling institutional structures.

Weak institutional contradictions capture a state were actors are less aware, or even unconscious of the prevailing institutional mechanisms and instead follow mimetic, normative and coercive behavior as rational and taken for granted action (Oliver, 1991). The institutional rules, norms and cultural-cognitive dimensions that actors are faced with and affected by are then widely spread and known. The action of actors is not challenged by strong contradictions and is therefore is less prone to question the existing institutional structure. Strong institutional contradictions address situations in which the existing institutional structures prevent actors from interpreting and considering *"critical information beyond institutional boundaries",* and does not stimulate active response (Seo et al., 2002).

While neo-institutional theory has argued that institutional structure makes actors blind to spot opportunities that would require going 'outside' current action and institutional structures, this reasoning does not hold when analyzing the cases. In three of the cases strong institutional contradictions emerged. Institutional contradictions were felt differently in each setting, and the resultant socio-cognitive dynamics then patterned the respective field in unique ways.

Interpretations and awareness of how the field of electronic publishing and printing would develop was highly divergent among actors that participated in field-level mobilizing and structuration during the mid 1990s. The shift from offset printing to digital printing was a radical change and a paradigmatic technological shift for both industries. Even though several researchers, and some innovative mid-size firms, had attended to the changes in the early phase in the mid 1990s, it was only by 2004 that field-wide awareness about the ongoing shift had started to form. Only then could productive field-level mobilizing and the initiation of field-level structuration progress. Strong institutional contradictions also emerged with field-level mobilization around well-being technologies in the mid 1990s. Struggles with field-level structuration in the health care sector increased awareness of the complex and multitude of institutional structures of the sector that was affected by the emerging field. Only by 2005 had field-level awareness strengthened around well-being technologies, which then enabled the productive mobilization of a third national technology program in the domain. As researchers in the functional foods field held high awareness in research-related properties of the field, industry actors in this field remained strongly embedded in the predominant technology specific logic. This prevented productive field-level structuration, and the emergence of novel value chain structures to be established in functional foods. This suggests that:

> **Proposition 8A: Wide-range awareness of novel technological opportunities is positively related to the effectiveness of field-level mobilization and structuration during situations of strong institutional contradiction.**

In the modular constructional steel industry, collaborative activities and engagement in development work was driven by high legitimacy of the endeavor. The legitimacy of institutional entrepreneurs as well as the legitimacy and familiarity of collaborative activities made it natural for actors to engage in field level structuration. This suggests that high levels of awareness was not needed because behavior was based on mechanisms of institutional isomorphic change, including coercive, normative, and mimetic processes (DiMaggio et al., 1983). Even though institutional entrepreneurial activities required high levels of awareness in the institutional change of steel construction, the wide legitimacy for engagement that was achieved was, for actors, more based on how the change was represented and how they pursued the legitimacy of institutional entrepreneurial action. This suggests that:

> **Proposition 8B: Wide-range awareness of novel technological opportunities is only weakly related to the effectiveness of field-level mobilization and structuration during a situation of weak institutional contradiction.**

6. MICRO-LEVEL FOUNDATIONS OF EMERGING TECHNOLOGICAL FIELDS

Based on the case analysis and developed propositions on field emergence, this chapter develops a micro-level foundation of emerging technological fields. The focus of the chapter is on factors influencing individual-level awareness and institutional entrepreneurship in emerging technological fields, and how these two issues are related. The chapter thus sets out to disentangle agency, interest, and action in novel technological fields by addressing individual-level awareness.

Field-level change and emergence is a complex, unpredictable, and challenging phenomena to both engage in and to comprehend. What then predicts awareness of technological field-level changes, opportunities, and challenges? Individual-level awareness is here considered to be the beliefs that he/she understands, beliefs that he/she and the organization is capable of and have the abilities to act upon, and the beliefs that he/she and the organization should act upon. This suggests that awareness enables the agency that may not resonate with the previous institutional logics. As those actors that hold lower levels of awareness in an emerging technological field follow the dominant logics, those with higher levels of awareness may conflict with this logic and be more aware of novel opportunities. In this respect, this thesis indicates that awareness is a central mechanism that enables institutional entrepreneurship. This chapter which is based on the case analysis, and the literature review, develops propositions about the factors that contribute to individual awareness, and how awareness is related to institutional entrepreneurship. In the final section a framework to analyze strategic options for institutional entrepreneurship is presented.

6.1. Initial accounts on individual-level awareness and institutional entrepreneurship

Four distinct properties that contribute to awareness were identified from the case study and by reviewing extant literature related to awareness in emerging technological fields. These findings indicate that awareness emanates from: (1) knowledge based expertise; (2) embeddedness in the technological field of the individual; (3) the social embeddedness of the individual; and (4) the organizational mobility of the individual. Propositions for the relationship between the four constructs and awareness are developed in section 6.1 to 6.4.

The case analysis indicates how both technological communities and actors such as Ministries, government agencies, and large firms, engage in institutional entrepreneurial activities in emerging technological fields. To account for these divergent positions around an emerging field and the related differing legitimacy and differently derived awareness of actors, two distinct variables of institutional entrepreneurship, network centrality and awareness, were included for proposition development. Network centrality was assumed to arise from the same elements as awareness, but with different pronunciations.

To capture institutional entrepreneurial action, the thesis separates real actions from visibility of institutional entrepreneurial action. While action accounts for the degree of activity of an actor, visibility of actors aims to capture how individual actors reach out and are considered as important to facilitating emergence of technological fields. To this extent this thesis aims to differentiate between different forms of action of institutional entrepreneurs that are more or less visible and which, in part, may impact the socio-cognitive dynamics in emerging technological fields. Propositions on how awareness and network position are related to visibility and institutional entrepreneurial action are developed in section 6.5 and 6.6. Two models are then set out to visualize the proposed relationships.

6.2. Expertise and awareness in emerging technological fields

The levels and depth of perception, insight and sense making, have been linked to expertise and competence of individuals. Recently, scholars have addressed the individual as a repository of organizational knowledge, as opposed to the notion that organizations are the main repository (Felin et al., 2007). Although the locus of knowledge and learning from this perspective is not context dependent, knowledge still resides in documents and practices. It is the individual that internalize prior knowledge, engages in learning and new knowledge creation, and enacts their knowledge in actions and engagements. Expertise includes high level of skills, talent, and knowledge (Subramaniam & Youndt, 2005). The contribution of ‘star’ scientists in knowledge exploration and exploitation has repeatedly been shown to be a skewed distribution of the research outputs of scientists as a whole, and only a few scientist seem to account for the main share of output (Narin & Breitzman, 1995). Star scientists have also been shown to positively affect the innovation output of firms (Rothaermel & Hess, 2007). During disruptive technology phases, star scientists can be better conceptualized as entrepreneurial individuals (Zucker & Darby, 2001). It is the level of knowledge and education among individuals that enables the capacity for knowledge creation (Smith, Collins, & Clark, 2005). Some scholars have conceptualized expertise as the intellectual human capital of individuals (e.g. Rothaermel et al., 2007). This framing of individuals as repositories of expertise includes two assumptions: (1) knowledge is accumulative and valued in society, and (2) expertise relates to high performance of the mind.

Experience relates to having lived through, and engaged in, prior activities in a technology domain. Prior experience and knowledge related to technology, its use, and its markets, are important for recognizing entrepreneurial opportunities (Scott, 2000). Experience influences the timing of engaging in exploring and exploiting technological opportunities. Katila and Mang (2003) have shown how organizations with experience are more likely to exploit earlier technological opportunities compared to those without prior experience. Here, this finding is argued to also hold at the individual level. As Felin & Hesterly (2007:207) have pointed out, *"current collectivist explanations may in some cases merely capture what are really the effects of differing individual inputs in skills and knowledge"*. This suggests that it is individuals that have expertise in an organization that are the underlying reason for firms to engage in early exploiting of technological opportunities.

It has been shown that individuals with experience are more confident and knowledgeable about different options and their feasibility (ref.). Studies also show how perception of competence influences an individual's perception of how controllable a situation is (Krueger, 2000). In this respect, it is not only objective knowledge properties, but also the subjective perception of being knowledgeable, for example gained through familiarity in a context or through an academic degree, that provides high status in society. Further, *"what you know affects who you know"* (Felin & Hesterley, 2007:206). Therefore, the social network and the community around a technology determine how knowledgeable the individual perceives himself/herself to be, which influences how controllable the situations appears to that individual. To conclude, the state of knowledge, here termed expertise, impacts awareness and sensemaking in an emerging technological field.

In the four technological fields examined in the empirical study, the cultivation stage triggered the development of university curricula that, in many ways, were shown to be critical in facilitating individual awareness. In the well-being technology field it was a newly qualified doctor working in a recently established laboratory in medical technologies based in the city of Tampere that came to have a central role in engaging in research in that particular field . In modular constructional steel, several of those that participated in teaching and research in modular constructional steel at universities in the 1970s became central actors during the early mobilization and structuration phase in the industry. In electronic publishing and printing those researchers who were active in field-level mobilizing had all undertaken their doctoral studies at the media technology laboratory. In the functional foods field, it was researchers that moved to the industry that were central to enabling early innovations in the field. The linkages evolved between public research organizations, such as research institutes and universities, and the research laboratories of larger firms in the food industry that provided fertile ground for supporting the dialogue between science and industry. These linkages were critical for facilitating inventions that incorporated LGG-bacteria in dairy products and the development of Benecol cholesterol lowering products. This suggests that:

> **Proposition 9: During the cultivation and early innovation phase of novel technology fields, individual awareness of technological opportunities and challenges is positively related to expertise.**

6.3. Individual embeddedness and awareness in emerging technological fields

Embeddedness of action in social relations and interpersonal networks has gained increasing attention as a research theme in social network studies. Embeddedness addresses the dependencies between behavior and institutions (Granovetter, 1985). Several authors have highlighted how networks influence expectations and opportunities of those engaged through their social embeddedness (Powell, 1990; Uzzi, 1997). Networks are better equipped and capable of interpreting new information, generating new interpretations, and disseminating information, than organizational hierarchies or market mechanisms (Powell, 1990:325). Embeddedness enables trust among actors and risk sharing, and spreads the costs of exploration and exploitation (Granovetter, 1985). Networks provide settings and exchange structures for freer and richer interpretation, debating, exchange, and communication between collaborative actors around an emerging technological fields. The expectations that form in networks make projections of the future more predictable and reduce monitoring costs (Uzzi, 1997). This suggests that expectations facilitate organization and order in networks. Larson (1992), in a study of entrepreneurial forms and collaboration, showed how expectation, obligation, common interest, and reputation facilitated greater collaboration and action through non-formal control compared to the more formal forms of control. It is therefore important to develop measures of network properties in order to understand better how expectations and awareness are linked to the embeddedness of actors in networks.

Embeddedness of action and the role of cohesive groups has also been conceptualized and described as ‘the small world phenomena’ (for an overview, see e.g. Fleming, King, & Juda, 2007). Research of the small world has reported a parabolic inverted u-shape relationship between creativity and network cohesion, and connectivity (Uzzi & Spiro, 2005). This finding shows how high social cohesion and social embeddedness stifles both interpretive and social interaction, thereby restricting change of communities (similar accounts have been described by Moody & White (2003)). The social capital of individuals and organizations has repeatedly been linked to knowledge production and learning advantages (Nahapiet & Ghoshal, 1998; Smith et al., 2005; Walker, Kogut, & Shan, 1997).

Embeddedness usually only considers the social dimension of embeddedness. However in technological fields actors also become embedded in the emerging technological setting because it often develops rather slowly during the cultivation and early innovation phase. While technological fields are knowledge intensive, the embeddedness of actors is not only attained through social relations but also through the knowledge accumulated by actors and their engagement in communities of practice in a technological field. Therefore, prior interaction and its range within a technological field provides the experience that advances subsequent interaction (Katila et al., 2003; Smith et al., 2005). This suggests that both the dyadic relationships of an actor as well as the overall network property are here included in the conceptualization of embeddedness (this argument is based on Granovetter (1992)).

With growing research in functional foods, researchers had increasingly pushed for funding and collaboration in the emerging functional foods field. During the first technology program, intensified collaboration among actors in the field further strengthened their vision and perception about how practices should be changed in the food sector in order to facilitate better emergence of the field. Many of the highly involved researchers and research managers explained how they convened weekly meetings related to research and development projects and other related field-level enabling activities. This provided them with an increasingly heightened awareness about opportunities. Top management in the larger firms in the food industry were on the other hand not actively engaged and lacked confidence in the novel technological domain, as on research manager explained:

> In research ... he was the closest friend when I discussed the possible commercialization of the Gefilus brand and the use of LGG bacteria… and also a professor at Turku … well I had presented this idea about trying a new approach for commercializing to the CEO and then it was moved to the firm's board and with their approval they also gave the additional instruction for this Gefilus thing that if we fail this second time our (the researcher director and the key research in this part) dried bones will hang at the main entrance of our headquarters …a little humor though but there was also this serious side that when it has now been decided it is like this.

Even though top management decided to go ahead, it was only the research director and the network of researchers in the field that clearly held a strong perception and belief about the technological opportunities in the field of functional foods. Similar mechanisms were present in the electronic publishing and printing field, with the research community become increasingly involved and engaged in the new technology through research and development projects.

> Well there was conflict and the firms which participated, many did not understand what is happening and we had this sub-project that focused on hybrid media systems ….and part of those firms that participated in the consortia did not accept this sub-project at all during the whole program period, and now this hybrid media thing is really topical….well the original idea on hybrid media came from VTT in 1993 when we had this project Printing and Publishing in 2020…we thought that these electronic tools are coming and in one way or other one should try to integrate the different communication medias better and then we came up with the idea that from printed material one would be able connect easily to electronic media. (a researcher at VTT)

The increasing involvement of these researchers with the international digital printing press manufacturers and active linkages to researchers in information technologies made them increasingly aware of technological opportunities for the paper industry and graphic arts industry. This indicates that:

> **Proposition 10: Awareness of technological opportunities and challenges is positively related to the social embeddedness of actors within an emerging technological field.**

> **Proposition 11: Awareness of technological opportunities and challenges is positively related to the technical embeddedness of actors within an emerging technological field.**

6.4. Awareness and mobility between organizational fields

Although expertise and embeddedness arise from accumulated knowledge and cultivation within a field, diversity of experience is not explicitly accounted for by these two constructs. In organizational contexts functional heterogeneity[47] has been found to correlate with the innovation capacity of individuals (Smith et al., 2005). Similar findings have been reported at the network-level and at the field level. Inter-organizational mobility of individuals in different organizational settings, and previous memberships in several communities, seems to advance reflective capacity due to awareness of different institutional settings (Battilana, 2006).

In the empirical study, several of those that engaged in institutional entrepreneurial activities had moved between a research and industry context during the cultivation and early innovation phase. The active director from Rautaruukki had previously worked at Helsinki University of Technology, at the National Research Institute of Finland VTT and in the agency Tekes; in each case being active in establishing and developing practices in the modular constructional steel field. Another individual that became central to facilitating and managing a large collaborative

[47] Functional heterogeneity here refers to diversity of stock of knowledge (Smith et al., 2005).

project for implementing product data exchange for constructional steelwork among engineering firms had earlier been a student during the first course on constructional steel at Lappeenranta Technical University. He later became the first laboratory director for the Constructional Steel Laboratory at Lappeenranta University of Technology. The case data also reveals how several firm research directors in the food industry who were active in the functional food programs, had a background in the biotechnology unit at the National Research Center of Finland VTT. The laboratory director of this biotechnology unit had also moved from research to industry and then back to research. These moves between different organizational fields attached to the emerging functional foods field appeared to strengthen individual's awareness and understanding about how to advance the field.

The previous literature and the evidence from the cases therefore indicates that awareness of the logics and governance that prevail in an institutional setting, increase with mobility across organizational field settings. Mobility across organizational fields, for example mobility from university to industry, or industry to research institute, is thus asserted to advance understanding of diverging institutional arrangements around a technological field. Individuals that have moved across fields are therefore *"less likely to see the prevailing institutional arrangements as taken-for-granted"* (Battilana, 2006:666). This suggests that:

> **Proposition 12A: Social embeddedness and mobility between organizational fields will interact in such a way that mobility will positively influence the interaction between the social embeddedness and awareness of an individual in an emerging technological field.**

> **Proposition 12B: Technical embeddedness and mobility between organizational fields will interact in such a way that mobility will positively influence the interaction between the technical embeddedness and awareness of an individual in an emerging technological field.**

6.5. Network centrality and awareness in emerging technological fields

This section focuses on the determinants of network centrality of individuals in an emerging technological field and how awareness is related to network position. As the empirical study did not specifically address the network structure, this section draws on previous research in the domain for developing propositions. However, the case study indicates that network centrality and technology field awareness may arise through distinct combinations of individual traits. For example, in the functional foods field, institutional entrepreneurship was dominated by actors who were active in several research and development projects, whereas institutional entrepreneurship in electronic publishing and printing and modular steel construction field emerged from less directly involved actors in the novel technological domain as well as engaged researchers. In addition, the active role of the Ministry of Trade and Industry, as well as a research director from the Social technologies laboratory at VTT, further supports this assumption about distinct socio-cognitive mechanisms that bring about network centrality and awareness in emerging technological fields. Thus, network centrality and technology field awareness may not both be necessary conditions for institutional entrepreneurship to form. This is further elaborated in section 6.6. The present section only focuses on reviewing research that addresses the antecedents of network positions in emerging technological fields and the findings concerning the relationship between network centrality and awareness.

With regard to dyadic relationships, the strength of the tie appears to advance the capability for knowledge creation (Smith et al., 2005), especially when complexity of knowledge increases (Hansen, 1999). This suggests that awareness is dependent on the ability to engage frequently with other actors in a technological field, and to build upon their knowledge and actors' interpretations. Both individual characteristics and formal position influence centrality in innovation work (Ibarra, 1993). Ibarra has drawn attention to how centrality is related to personal sources of power. These sources of power originate from experience, seniority, education, and professional activity. In this regard, informal sources of power, as opposed to formal sources such as hierarchy and organizational position, provide the agency that productively enables innovation. Although Ibarra's study focused on organizational contexts, the same mechanisms are assumed to be present at the field level in inter-organizational networks. The capacity to understand and make sense of complex emerging technological environments, and the ability to understand and cope with the social and the institutional context is rewarded by the network through the allocation of central administrative innovation roles to these individuals.

The size of an organization influence how separated the technical and administrative innovation activities are. In smaller firms both tasks are usually taken by the top management, whereas in larger firms these roles are often separated (Damanpour, 1988). Awareness, interpretation, and understanding of an emerging technological field by the top management of larger firms are therefore less embedded and more based on their interpretation via research and development directors and personnel. The availability of economic resources increases the overall rate of formation of network ties (Koka et al., 2006). Where government funding for applied research and technology development is available tie formation should increase. The resources of larger firms attract smaller firms toward innovation. Smaller firms are usually resource poor and thus are inclined to build connections and links to larger firms. This is due to the resources (informational, technological, and market) and legitimacy provided by these ties (Larson, 1992). In situations of higher environmental uncertainty firms seem to favor previous network relationships over new ones (Koka et al., 2006). The field centrality and propensity for action in collaborative R&D influence an actor's network evolution and dynamics in important ways. This suggests that:

Proposition 13A: Network centrality is positively related to expertise.

Proposition 13B: Network centrality is positively related to technical embeddedness.

Proposition 13C: Network centrality is positively related to social embeddedness.

Proposition 13D: Network centrality is positively related to field awareness.

The outlined propositions concerning the emergence of individual awareness and network centrality detailed in section 6.1-6.4 are outlined in model 1 below.

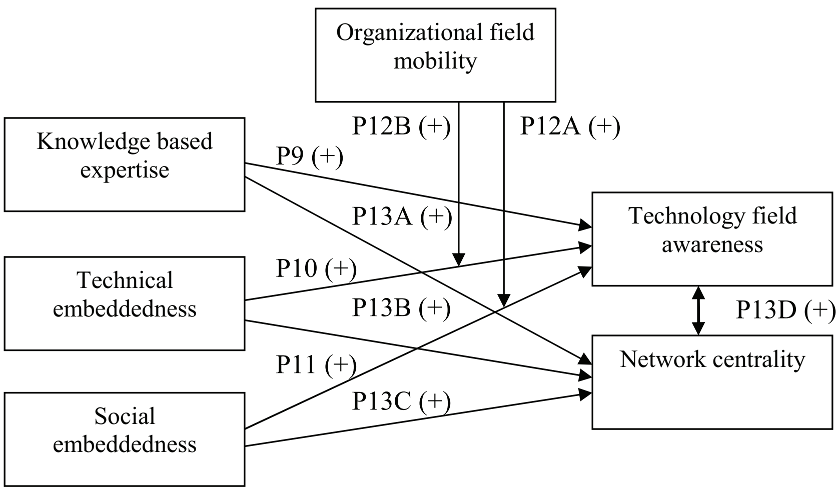

Figure 6-1 Emergence of individual-level awareness and network centrality (model 1)

6.6. Individual-level propensity for institutional entrepreneurship

This final section addresses in more depth the assertions of the previous section concerning the relationship between network centrality and technology field awareness of individuals, and how these are related to institutional entrepreneurial visibility and action. It is important to distinguish action from visibility: the latter addresses legitimacy, interpretability, and the ability to reach other actors in a field, while the former only attends to activities that may become visible, but may also not become visible.

6.6.1. The micro-macro relationship of institutional entrepreneurship

This section commences by untangling the multi-level properties of agency and action by considering awareness and network properties as constructs that mediate between the micro- and the macro-level of a field. Several scholars have highlighted the gap in research in linking network structure to action (Stevenson et al., 2000). By simultaneously addressing agency and action, and relating these to awareness and network positions, a multi-level analysis of emergence in novel technological fields is developed. The main argument is that *awareness induces agency*. It is through awareness that one may start to untangle how underlying institutions and structures play a role in enabling interest and agency in novel technological fields. The impetus for action arises from the level of awareness of actors about the need to reshape and change current structures and institutions and the identification of opportunities that result from new technologies and related development needs. The explanatory variables for awareness are experience, social and technological embeddedness, and network centrality. High levels of awareness reflect individuals with a high ability high to engage in information processing. A recent study by Wegner et al. (2004) showed how thoughtful attitudes are related to high levels of information processing. Thoughtful attitudes are "*more likely to generate scrutiny and well-considered counterarguments and, thus, to be less susceptible to persuasion than attitudes based on lower levels"* (Ford, Ford, & D'Amelio, 2008:369). Battilana (2006) has distinguished between ability to act and willingness to act. Awareness increases the motivation to act and more frequently engage with other individuals with expertise in the domain, in searching for uncertainty reducing cues, and support for making sense of an emerging technological field. To this extent institutional entrepreneurs try to realize the value from emerging technological fields. In Latour's (2005) framing, institutional entrepreneurship is about assembling associations and advancing the formation and shaping of new associations. To take account of the distinction between ability and willingness to act, awareness and propensity for institutional entrepreneurial action is separated.

6.6.2. Awareness, network centrality, and visibility of institutional entrepreneurs

From positions of network centrality individuals gain a significant base of influence and power in a network (Battilana, 2006; Brass, Galaskiewicz, Greve, & Wenpin, 2004; Ibarra, 1993). Being influential depends on both formal authority and network centrality. Thus, having low levels of either of these concerns reduces the power of an individual to introduce institutional change (Battilana, 2006). Formal authority may stem from a higher organizational position or institutionally supported agency. With lower legitimacy an individual will not engage in institutional entrepreneurial action to the same extent, due to a foreseeable lack of ability to gain followers. Different positions in a field provide different opportunities to act as an institutional entrepreneur (Battilana, 2006). Central network positions provide a rich environment with high levels of information and resource flow and the availability of these assets. This provides indvidusals with central positions great influence (Dhanarag & Parkhe, 2006). Centrality, also appears to facilitate engagement of individuals in change programs (Stevenson et al., 2000). Positional advantages have been reported to increase innovation performance at the inter-organizational level (Tsai, 2001). This positional advantage of an organization in a network is assumed to also hold at the individual level in the relationship with the technological community in an emerging technological field. This said, the centrality benefits of organizations also translate into individual agency. Organizational characteristics such as firm size and embeddedness in the field influence the agency of individuals and consequently their action.

Building on Emirbayer & Mische's (1998) work on constitutive elements of agency, depending on the uncertainty that a new technology brings in an industry and a technological setting, distinct elements of agency are accentuated. Under situations with high uncertainty projective characteristics of agency are accentuated. Therefore, with high uncertainty, there should be an increase in institutional entrepreneurial activities coming from actors that are active in projective work; for example researchers and research directors in firms. In the digital publishing and printing field it was centrally positioned researchers who engaged in field mobilization and structuration. Also, in the area of functional foods where abundant uncertainties were present concerning technology specific logics, the majority of institutional entrepreneurial activities emerged from researchers and research directors. In low situations with uncertainty agency is based on iterative and normative agency, where action follows established processes and organizational arrangements. Because modular constructional steel appeared complementary rather than threatening for actors in the field, mobilization and field-level structuration was furthered by established actors in the industry. Although one researcher was highly active there were fewer institutional entrepreneurial activities arising from universities and researchers in these phases.

Field-level structuring activities take place in standardization committees, industry associations, professional associations, and ministerial programs and legislative committees. These groups and platforms are rather formalized forums. More informal and ad hoc type forums may form as open Sometimes innovation communities, where brokerage, boundary spanning, and leadership become formalized. Technical contributions and active participation in an emerging technological field facilitates the propensity to become involved in administrative roles in the community, and the subsequent visibility of actors (Fleming & Waguespack, 2007).

Visibility refers to an actor's visibility among other actors that participate in an emerging technological field. During the empirical interviews in each of the four cases, certain actor's role in visioning and being active in facilitating emergence of the field was repeatedly mentioned. This indicates that some actors had been more visible than others. The case analysis illustrates how visibility is a form of agency, that forms through an actor's ability and reach for visioning, legitimating, framing, boundary spanning communicating, and mobilizing that, in important ways, influence structuring of the field. Visibility may arise from the time spent in a community, as was the case for the research director from Social technologies laboratory at VTT who engaged in productive field mobilization in mid 1990s and had consistently worked with well-being technologies since the early 1970s. The longer the time spent in the community, the more likely an individual is to be also known and visible. In the case of well-being technologies, this visibility, in part, supported the facilitation of the first program in the well-being technologies field.

But institutional entrepreneurial action may also be less visible. In the electronic publishing and printing field a researcher from VTT was visioning about how digitalization was going to disrupt both the paper industry and the graphic arts industry value chain. Several ideas and concepts were then developed to address this shift, such as hybrid-media and digital pens. Due to the legitimacy constraints of the presented disruption the actor did not receive prominent visibility in the early stage. It was only with increasing technical and social embeddedness and the gradual clarification of the forthcoming paradigmatic shift that provided increasing visibility to this actor.

This suggests that it is the combination of intent, ability, and awareness that result in action that is more or less visible. The action by institutional entrepreneurs to influence the emergence of technological fields is hence visible to different extents. The following four propositions are outlined accordingly (figure 6-2):

> **Proposition 15A: Institutional entrepreneurial action is positively related to the technology field awareness of individuals in an emerging technological field.**

> **Proposition 15B: Institutional entrepreneurial action is weakly but positive related to the network centrality of individuals in an emerging technological field.**

> **Proposition 15C: Visibility of institutional entrepreneurial action is positively related to the awareness of individuals in the emerging technological field.**

> **Proposition 15D: Visibility of institutional entrepreneurial action is positively related to the network centrality of individuals in an emerging technological field.**

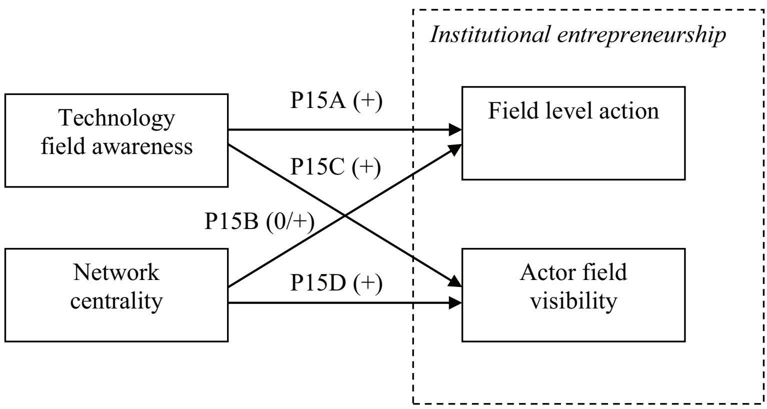

Figure 6-2 Emergence of institutional entrepreneurship (model 2)

6.7. Institutional contradictions and institutional entrepreneurship

Although, in their conceptual work on institutional contradictions, Seo & Creed (2002) have theorized how agency emerges in institutional contexts, they do not further elaborate on the different options institutional entrepreneurs have and how they may be constrained in facilitating emergence of novel fields. In this respect, previous research seems not to have addressed questions about the effectiveness of institutional entrepreneurship. In section 5.4, propositions regarding how institutional contradictions and awareness in emerging technological fields are related were outlined. These propositions suggest that institutional contradictions, depending on whether they are weak or strong, confront actors with different socio-cognitive dynamics. When an emerging technological field is confronted by weak institutional contradictions, institutional entrepreneurship is based more on formal authority and scarce and valuable resources (Hardy et al., 1998). When an emerging field generates strong institutional contradictions, discursive legitimacy is accentuated towards supporting shifts in technology specific logics and innovation logics. These distinctions translate into a framework (Figure 6-3) that enables differentiating between the institutional entrepreneurial positions in a field with regard to the institutional contradictions, and the respective institutional challenges that are faced by institutional entrepreneurs.

	WEAK INSTITUTIONAL CONTRADICTIONS	STRONG INSTITUTIONAL CONTRADICTIONS
LOW LEVEL OF AWARENESS	*Basis of interpretation:* No active questioning of current action or action proposed. *Basis of action:* Routines, scripts, and institutional behavior.	*Basis of interpretation:* No active questioning of current action. Hostility to change. *Basis of action:* Routines, scripts, and institutional behavior.
HIGH LEVEL OF AWARENESS	*Basis of interpretation:* Questioning of current action and knowledge structures. Adaptation and engaging in change. *Basis of action:* Mindfulness, institutional entrepreneurship, and gradual change of institutional basis.	*Basis of interpretation:* Questioning of current action and knowledge structures. Embracing and engaging in radical change. *Basis of action:* Mindfulness, institutional entrepreneurship, and actions for institutional change.

Table 6-1The basis for interpretation and action in emerging technological fields

The framework also suggests several options that institutional entrepreneurs may pursue in facilitating productive emergence in emerging technological fields. In situations of strong institutional contradiction institutional entrepreneurship can either engage in supporting an increase in field-level awareness or can choose to reframe and legitimize institutional change in such a way so that institutional contradictions are less pronounced and conceived as weak institutional contradictions. In situations of weak institutional contradiction, institutional entrepreneurs can either engage in facilitating field-level awareness by theorizing and educating (Hardy et al., 1998), but may also choose to facilitate institutional change through formal authority or by drawing on scarce or critical resources (Hardy et al., 1998).

Although institutional entrepreneurship as theorized in previous sections, includes a strong awareness about an emerging technological field, those attached to the emerging technological field do not require to be education in the field in order to enable institutional change. Rather, institutional entrepreneurs may choose to reframe and legitimize novel technology specific logics and innovation logics through robust design strategies (Hargadon et al., 2001). This is important because choosing different institutional entrepreneurial strategies is reflected in different paths, speeds, and costs of institutional change. This suggests that institutional entrepreneurs may be positioned in such a way so that certain strategies are more or less possible than another.

In the modular steel construction field, the firm Rautaruukki possessed scarce and critical resources that facilitated the firm and its actors to engage in framing, strategic maneuvering, and the legitimization of institutional change in such a way so that only weak institutional contradictions emerged. With the functional foods technology field, researchers and research directors lacked the formal authority and legitimacy required for reframing the shift, and therefore chose to engage in educating actors and facilitating increasing awareness about the emerging technological field and its challenges. This strategy was highly resource demanding and resulted in an institutionalized research logic around functional foods that was difficult to embrace in the industry setting.

To conclude, this chapter has outlined micro-foundations for emerging technological fields. Together with the previous theorized field-level socio-cognitive dynamics the two preceding chapters address the complex socio-cognitive dynamics that occur between the micro- and the macro-level in emerging technological fields.

7. DISCUSSION AND CONCLUSIONS

This thesis aimed to advance understanding about socio-cognitive dynamics in emerging technological fields by addressing institutional entrepreneurship, awareness, and institutional contradictions. Towards this end the thesis has developed an institutional sociological approach to study technological fields as a specific form of institutional field with distinct socio-cognitive mechanisms and emergent properties. By studying institutional entrepreneurship, awareness, and institutional contradictions, the thesis addresses the central enabling and constraining factors that shape micro and macro-level emergent properties around novel technological fields. This framing provided directions for examining three related elements of emergence: the emergence of awareness and institutional entrepreneurship, the emergence of institutional contractions, and the distinct stages, dynamics, and paths of technology field emergence. The empirical study addresses four emerging technological fields, which to various degrees disrupt institutionalized technology-specific logics and innovation logics. In this respect this thesis addresses Maguire et al. (2004:675) call for research that *"systematically compares and contrasts institutional entrepreneurship in emerging and destabilized fields (and mature fields)"*.

The following sections present a synthesis of findings of the empirical study, the limitations of the study, theoretical and methodological implications, and practical implications. The chapter concludes by outlining future avenues for research on institutional entrepreneurship, awareness, and institutional contradictions in emergence of technological fields.

7.1. Synthesis of findings

The analysis indicates that knowledge based expertise, social embeddedness, and technical embeddedness tend to advance individual-level awareness. Organizational field mobility of individuals appears to positively influence this relationship. Although network centrality appears to emanate from the same underlying variables, their pronunciations are different. The initial findings from the four case studies suggest that both awareness and network centrality facilitate institutional entrepreneurial action, while visibility seems only to be strongly related to awareness.

The thesis identifies institutional entrepreneurship in emerging technological field as arising from actors with substantial expertise in the novel technological field, incumbent industry actors in the predominant technological field reclaiming their position, and government actors in response to societal challenges. Institutional entrepreneurs who hold broad-range legitimacy appear to facilitate productive field-level mobilization and structuration. Institutional entrepreneurs that engage in strategic field-level work in opposition to non-strategic and reactive agency are also related to the productive emergence in novel technological fields. Depending on how novel technologies penetrate or emerge within or outside predominant technological structures they are attended to in different ways by actors. This is also why institutional entrepreneurs engage in different strategies when technologies emerge endogenously within the field or appear as external technological advancements that require adaptation. When new technologies create ambiguities and highly diverging views on prospective use and underling technology-specific logics, projective capabilities become accentuated for institutional entrepreneurial action. To this extent, researchers have a high propensity for institutional entrepreneurship. In situations when new technologies in an emerging field are less ambiguous, agency is based more on iterative and normative legitimacy, and incumbent actors and actors possessing scarce and valuable resources such as big firms and government actors are thus more prone to take institutional entrepreneurial action.

The second element of emergence addresses institutional contradictions. In examining institutional contradictions, the thesis comes to distinguish the strong institutional contradiction from the weak. With higher diversity and inconsistent accounts of stakeholders with respect to the emerging technology field logics, institutional contradictions are stronger. This distinction helps to understand different options and viable strategies for institutional work (Lawrence et al., 2006) by institutional entrepreneurs in a distinct setting. This thesis differentiates between institutional entrepreneurial strategies (1) reframing and legitimizing novel technology specific logics and innovation logics, from strategies (2) educating actors and theorizing the shift. Although both strategies are valuable for advancing institutional change, they have different challenges that it is important to identify. Reframing and legitimizing an emerging technological field requires institutional embeddedness of technological artifacts, the symbolic system, the relational system, and practices of an emerging technological field with regard to the predominant technological field. Productive institutional embedding work requires substantial field-wide legitimacy of institutional entrepreneurs. Legitimacy is important for negotiating and proposing alignment and for gaining productive feedback about embedding the carriers of the novel technological field. In addition, a wide understanding of the context and partaking organizational fields is valuable for outlining the compelling strategies and visions for change. This strategy does not require substantially increasing the awareness of actors, but is more about decreasing contradictions that the novel field and institutional entrepreneurial action triggers. Educating and theorizing a novel technological field rests on the idea that institutional change is facilitated by increasing understanding and conceptualization of the new technology, resulting in higher awareness. The case study shows how institutional entrepreneurs may engage in increasing awareness through, for example, standardization, active public communication, and wide-range diffusion of the symbolic system through university curricula and professional courses. Field-wide awareness is also advanced through synergistic development of institutional carriers of the novel technological field.

The third element of emergence considers the longer term emergence of technological fields. The thesis reports four stages in technology field emergence: a cultivation and early innovation phase, an early mobilization and structuration phase, a field mobilization phase, and a field structuration phase. Each phase holds distinct socio-cognitive mechanisms that pattern emergence. Transitions from one phase to another and the following socio-cognitive dynamics in the subsequent phase is based on (1) the prevailing socio-cognitive dynamics and resulting institutional entrepreneurship and (2) the stage of development of institutional carriers of the novel technological field. The thesis shows how productive mobilization and field-level structuration depends on (1) the wide-range diffusion of the symbolic system, (2) the abundant presence of technological artifacts, (3) the broad-range legitimacy of institutional entrepreneurs, and (4) the wide-range legitimacy of field-level mobilization. It is the interaction and synergies between these four elements that importantly influence the pace and productivity of institutional change in technological fields.

7.2. Limitations

As is the case with all empirical research, this study is not without limitations. Three limitations of the study are discussed. The first limitation relates to the generalizability of the developed propositions. By including only four cases the study might have limited generalizability. However, the long term perspective for the case studies and the focus on both micro-level and macro-level emergent properties are valuable especially for comparing findings from other similar longitudinal studies of industry emergence and technology field emergence. Thus, by using previous research and the comparable reported cases and literature on these topics the analysis and the development of propositions are strengthened. Also, as the study followed an inductive research methods approach, the four cases have been central in informing the development of more general theory about conceptualizing and studying technological fields as inter-institutional structures. To this extent the case analysis itself has been substantially shaped by the in-depth analysis of the literature used for the theoretical framing. This particularly applies to the neo-institutional sociological stream of literature. Towards these ends, the thesis has followed a consistent and systematic use of concepts and constructs.

A second limitation is the distinct context of Finland and national technology programs. Finland is pictured a social-corporatist nation (Jepperson, 2002) where collaboration and coordination has been described as to go beyond traditional market-based interactions. Although this might hold true for certain industries, the overall diversity of resistance versus embracement of collaboration in the four cases should, in part, depute generalizations. Although national technology programs were, and still are, part of the technology and innovation policy in developed countries, many nations do not have such coordinated schemes. Further, national technology programs in Finland are comparatively large in volume and in participation and are comparatively hands-on initiatives compared to the initiatives in other countries. Funding from Tekes is also geared towards specifically enhancing inter-organizational collaboration and collaboration across public research and industry. Among OECD countries, Tekes funding scores highest in degree of collaboration within funded research and technology development projects (Tekes website). These specificities of technology policy and the national technology programs are a limiting factor for the generalizability of the findings.

The third limitation is connected to the paradigmatic shift of the digitalization and the expansive growth of information and communication technologies around the world. Although this shift had only just begun when the four studied fields were mobilized, it started to change the interaction and interfaces of individuals and organizations in many ways. Socio-cognitive mechanism and emergence are therefore in a transforming reaction and it is unclear how much the reported findings are partly related to this shift and partly the more general properties of emergence of technological fields. This is a challenge when studying technological change, and addresses Yin's (2003:113) caution with regard to case studies and theory development being weak in accounting for underlying larger forces, so called 'super rival' explanations, that may importantly influence observed dynamics. Future research should address this question more carefully.

7.3. Theoretical and methodological implications

The thesis develops several important themes that advance theory on the emergence and socio-cognitive dynamics of technological fields. First, it has developed analytical tools and concepts to study technological fields as collective meanings structures and an arena of multiple institutional logics. This conceptual model is presented in Figure 2-1. To untangle the emergence of technological fields, the thesis then outlines the four elements of institutional carriers of technological fields based on the model put forward by Scott (2008). A model of technology field-level shifts is then presented that distinguishes between changes in technology-specific logics and innovation logics in order to better capture socio-cognitive dynamics, specifically institutional contradictions and the challenges faced by institutional entrepreneurs around emergent technological fields. In this regard, the developed analytical models and concepts enable one to study technological field as a distinct arrangement of an organizational/institutional field. The vast literature and research on fields provide a valuable source on which to draw with regard to methodological and theoretical accounts. This stream of research has also produced a vast amount of empirical research on institutional persistence and change, and therefore provides empirical research with which to compare. Though studies on institutional phenomena needs to consider local contextual characteristics, this thesis also shows how institutional and socio-cognitive mechanisms have some fundamental properties that hold between different settings. This is why studies on technological fields can inform theory on organizational fields and thereby strengthening this productive dialogue between studies of the social and the cognitive, and how these are related to action.

Second, the thesis advances theory by comprehensively addressing institutional embeddedness in a field. The thesis considers four institutional carriers; (1) technological artifacts, (2) organizational and inter-organizational routines, (3) the relational system, and (4) the symbolic system, as the most central elements that become institutionalized in technological fields. Although previous studies have focused on one or two of these carriers, the original framework described by Scott has not evoked studies on how each of the carriers develops and changes in concert over time. By considering each carrier with their underlying and evolving characteristics in interaction with each other within a single study, one may better capture the underlying socio-cognitive mechanisms of deinstitutionalization and institutionalization in fields. This framing also helps to explain how and why institutional entrepreneurship emerges in different locations in an inter-organizational field and at certain phases of field emergence. This is why it is important to consider the distinct properties of embeddedness of actors in fields and to inform better theory in terms of generalizations and distinct contextual properties.

Third, the thesis connects the micro- and macro-level processes by simultaneously considering institutional entrepreneurship, awareness, and institutional contradictions. While previous research has focused on one of these, this thesis shows how important it is to study all three at the same time because they are related and together influence subsequent emergence. The thesis contributes to theory by linking micro-level properties of individual awareness to macro-level emergent properties of a field, specifically focusing on institutional contradictions. Awareness, though diffused among actors in a technological community, does not imply the adherence of stakeholders and their embracement of novel technologies. The emergence of awareness is critically linked to how productively institutional entrepreneurs frame and mobilizes institutional change. Equally, these emergent properties are dependent on the timing of institutional entrepreneurial activities, with regards to the stage of emergence of institutional carriers of technological fields. This is why productive institutional entrepreneurship is different in different institutional settings. Also by attending to awareness, institutional entrepreneurship, and institutional contradictions, informs previous research on *"how external events enter the institutional environment"* of industries (Hoffman & Ocasio, 2001:432). The thesis explains how attentional processes are dependent on awareness which is related to the institutional contradictions and emergent characteristics of institutional entrepreneurship. To conclude, institutional entrepreneurship is determined by institutional contradictions that arise between institutional carriers of the predominant field and the emergent field, and how strong these contradictions come to be perceived by actors.

Fourth, the thesis provides a broader approach to the antecedents of institutional patterns and change of these patterns. While previous studies have attributed a dominant role to collective actors and institutional entrepreneurs in enabling shifts in institutional bases, this thesis argues for an integrated approach that in addition to the two for mentioned, also considers the institutional properties of technologies and the respective dynamics of change of technological fields. While previous studies on fields have focused on organizational isomorphism, future studies could more carefully address *technological isomorphism* and how technological fields hold properties of *"formal collective action"* that *"increases system coherence, promotes stability and structuration"* and in this regard include elements for institutionalization (Zucker, 1988:23).

As a final note, the emergence of technological field at a global level has not been explicitly addressed in this thesis. This said, the thesis provides important indications of the nature and complex interaction between the local and the global setting of emerging technological field. These interactions have become increasingly important, and provide an avenue for further research.

7.4. Practical implications

This thesis has practical implications on many levels. First, the thesis informs actors, including individuals, networks of actors, and organizations that engage in institutional entrepreneurial activities about the different challenges in facilitating emergence of technological fields. The thesis shows how educating and theorizing is more valuable during early stage of field emergence while institutional embedding is central during field mobilization and for engaging actors in productive field structuration. In this respect, depending on the stage of emergence of a technological field, certain types of institutional work and enabling activities are more productive than others.

Second, the thesis has practical implications for innovation policy. The thesis shows how the different phases in emergence of technological field require different incentives for directing productive socio-cognitive dynamics in each phase and the transitions between stages. This is challenging because policy planning needs to identify the current stage that a technological field is in. It also requires understanding of the institutional environment that an emerging technological field is challenging. It requires the identification of possible emergent institutional contradictions and how strong they are for evaluating suitable incentives. Equally, policy makers can, to a certain degree, influence how institutional contradictions emerge and how strong they become by facilitating actors with more or less legitimacy in institutional entrepreneurial action. Addressing institutional contradictions is important especially when they are strong, as small and medium size firms can not expand and grow when technology specific logics are ambiguous and unsettled.

Although addressing institutional contradictions is challenging post hoc, the empirical study also reveals how policy makers have already encountered institutional contradictions, developed further understanding about these complex dynamics, and how to engage as a facilitator for enabling emergence of technological fields. A final causation that emerges from the empirical study is the possible threat of engaging in too strong a fashion with shaping field emergence. The cases show how emergent properties are, in many ways, unpredictable and may take unanticipated paths, especially as socio-cognitive dynamics are changing with the ongoing transition to a digitized and increasingly connected global awareness space.

7.5. Future avenues for research

The theoretical advancements outlined above provide several avenues for future research. While the empirical study focused on emergence of technological fields in four different institutional settings in Finland, future studies could advance a global perspective by studying emergence of technological fields at the global level, and studying how different national and economic regions develop in relation to the ‘global’ technological field. As previous research has mainly studied emergence of technological fields’ ex-post, future research is needed in order to capture better the ongoing unfolding of socio-cognitive dynamics. Greenwood and Hinging (1996:1047) have made similar arguments about the need for detailed comparative case studies, in real-time, on institutional change processes of organizations, as power, interest and leadership are *"difficult to measure"* and are *"highly sensitive to context in their operation"*. These challenges are similar to those when studying institutional change at the field-level, although field-level shifts ranges over a longer period of time. To this extent, future research should carefully document and follow changes in awareness, institutional contradictions, and institutional entrepreneurship as an ongoing process.

As this thesis has outlined a framing of technological fields as inter-institutional structures, it should provide a fruitful avenue for further investigating institutional and socio-cognitive mechanism in emerging technological fields. At the micro-level, further research is required in order to understand how institutional entrepreneurship transfers from actor to actor and how the ideas and general properties remain or change, and if so in what way. Further research should also be directed at studying awareness as it changes, and to test biases of ex-post studies on awareness. The outlined frameworks and concepts also provide innovation network research with directions for studying how awareness is distribute in networks, and how the resultant awareness landscape is related to institutional contradictions. Network analysis is valuable for further investigating how awareness diffuses in networks, and how, in different ways, strong and weak ties may influence how awareness diffuses and strengthens.

To conclude, the thesis has outlined an institutional sociological approach to study the interplay between the micro and macro-level emergent properties in novel technological fields. This framing and the initial propositions concerning both micro and macro-level emergent properties in novel technological fields should provide a solid base to further study of these complex dynamics.

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APPENDIX A. THEMES OF THE SEMI-STRUCTURED INTERVIEWS

The interviews followed a semi-structured interview structure. Following themes were covered during the interview.

1. Background of interviewee and how he/she became active in the emerging field

2. Starting point and context

- What was the starting point for the program?
- How was the situation of industry competitiveness?
- How would you describe the program target sectors community before the program?

3. Program planning

- How was the program planning phase
- Who participated in the planning?
- How did the planning progress?
- What was the commercialization focus during the planning?
- Who did the ideas of commercialization change during the program?

4. Program execution

- How was the interaction and collaboration between participants during the program?
- How did the community of practice change during the program?
- How did the interaction and dialogue between different stakeholders develop or change?
- How would you describe the role fo different stakeholders and their activities in the program?

5. The targeted community after the program

- How was the community developed after the program?
- How has the developed technologies, products and services been taken into use?
- How have the investments in the community developed?
- How did international collaboration develop during the program and after it?

6. Motivation for working with the emerging technology field?

APPENDIX B. LIST OF INTERVIEWEES

ID	Modular steel constructional steel field	Functional foods technology field	Electronic publishing and printing field	Well-being technology field	Firms	Research institutes and university	Government agency and ministry	Other organization	Involvement during mobilization and/or structuration (H=High, M=Medium)	Involvement 2005 (H=High, M=Medium, L=Low)
01	x				x	x			H	L
02	x				x				H	M
03	x					x			M	M
04	x					x			H	H
05	x							x	H	H
06	x				x				H	H
07	x						x		M	L
08	x				x				H	L
09	x				x				H	L
10	x						x		H	M
11		x			x				H	H
12		x					x		M	M
13		x			x				M	M
14		x				x			H	H
15		x				x			H	H
16		x					x		H	M
17		x				x			H	H
18		x			x				H	M
19		x					x		H	H
20		x						x	M	L
21		x					x		M	L
22		x					x		H	L
23		x					x		H	L
24		x			x				H	H
25		x						x	H	H
26			x		x				H	M
27			x			x			H	H
28			x		x				H	M
29			x				x		M	L
30			x				x		H	M
31			x				x		H	L
32			x			x			H	H
33			x			x			M	H
34			x		x				H	H
35			x			x			H	H
36				x		x			H	H
37				x			x		H	L
38				x			x		H	H
39				x				x	H	H
40				x	x				M	M
41				x		x			H	H
42				x			x		H	H
43				x			x		H	H
44				x			x		M	L