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An innovation systems framework for analyzing the impact of mature industries on emergent industries

Allan Dahl Andersen
University of Oslo
TIK Center for Technology, Innovation and Culture
allanda@tik.uio.no

Tuukka Mäkitie
University of Oslo
TIK Centre for Technology, Innovation and Culture
trmakiti@tik.uio.no

Jens Hanson
University of Oslo
TIK Center for Technology, Innovation and Culture
jens.hanson@tik.uio.no

Håkon Endresen Normann
University of Oslo
TIK Center for Technology, Innovation and Culture
h.e.normann@tik.uio.no

Taran Mari Thune
University of Oslo
TIK Center for Technology, Innovation and Culture
t.m.thune@tik.uio.no

Abstract

State of the art: Industry emergence and diversification have been widely discussed through 'relatedness' (Boschma & Frenken, 2011) and 'path creation' (Garud & Karnøe, 2001). However, the former tends to simplify conceptualizations and rely on large longitudinal data sets, and the latter currently lacks a strong analytical

framework. Meanwhile, technological innovation systems (TIS) has emerged as a framework to analyze and conceptualize new technologies. The focus is on system components (actors, institutions and networks) whose interaction can support or hinder development and diffusion of a technological field. These actions unfolding under the influence of other components are translated into system functions (e.g. knowledge development, legitimization) which drive system evolution (Bergek et al., 2008). Research gap: The existing TIS literature has been criticized for failing to conceptualize and systematically analyze how an emergent TIS interacts with its context (Markard & Truffer, 2008). Bergek et al. (2015) have recently drawn attention to this issue and suggested a future research agenda including various forms of TIS-context interactions which one concerns as structural couplings between different TIS's. We elaborate on the latter to propose a framework for identifying and analyzing the structural couplings between mature and emergent TISs. We ask: how can we analyze the impact of a mature industry on an emerging one? Theoretical arguments: We argue that novel TIS's often interact with mature TIS's, and these connections can be analyzed through structural overlaps. We suggest that such interactions can have positive (complementary) or negative (competitive) effects on the emerging industry. We identify five dimensions of structural coupling: actors, networks, institutions, technology and infrastructure. We believe that analyzing these overlaps can be useful in understanding how an established industry affects the development of a TIS by supporting or hindering its system functions. Method: First, we review several literatures on the interactions between new and mature industries covering evolutionary economics, economic geography and transition studies. Second, on this basis we identify the research gap and, third, suggest a novel elaboration of the TIS framework to address this research need. Fourth, on the basis of existing literature and secondary data, we illustrate the framework of interactions through a case study of structural overlaps between the offshore oil and gas (O&G) and offshore wind power (OWP) in Norway. Results: The paper proposes an extension of the TIS approach that allows us to study how the emergence of novel industries interacts with mature industries. Such understanding can be useful in creating more effective policies for supporting clean-tech innovations. Additionally, our case study results show that significant structural coupling exist between O&G and OWP in different parts of the supply chain, for instance in terms of technology and know-how. Such notions give insights regarding the potentials of industrial diversification of O&G related companies to other industries. References: Bergek, A., Hekkert, M., Jacobsson, S., Markard, J., Sandén, B., & Truffer, B. (2015). Technological innovation systems in contexts: Conceptualizing contextual structures and interaction dynamics. Environmental Innovation and Societal Transitions. doi:10.1016/j.eist.2015.07.003 Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., & Rickne, A. (2008). Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. Research Policy, 37(3), 407-429. doi:10.1016/j.respol.2007.12.003 Boschma, R., & Frenken, K. (2011). The emerging empirics of evolutionary economic geography. Journal of Economic Geography, 11(2), 295-307. doi:10.1093/jeg/lbq053 Garud, R., & Karnøe, P. (2001). Path Creation as a process of mindful deviation. In R. Garud & P. Karnøe (Eds.), Path dependence and creation (pp. 1-38): Lawrance Earlbaum Associates. Markard, J., & Truffer, B. (2008). Technological innovation systems and the multi-level perspective: Towards an integrated framework. Research Policy, 37(4), 596-615. doi:http://dx.doi.org/10.1016/j.respol.2008.01.004

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Path branching as system building: An innovation systems perspective on the interactions between emerging and mature industries

Allan D. Andersen, Tuukka Mäkitie, Jens Hanson, Håkon E. Normann, Taran M. Thune

TIK Center, University of Oslo, Norway

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1 Introduction

The inter-industry dynamics between, on the one hand, established and mature industries, and, on the other hand, emerging and immature industries have been understood as central for industrial advance and economic development by a range of prominent thinkers associated with evolutionary economics (Dahmén, 1950; Hirschman, 1958; Schumpeter, 1934). The complex issue has recently received renewed attention firstly in the academic area of economic geography under the notions of 'related variety' and 'path branching', and secondly, in the area of environmental innovation studies where a key framework – technological innovation systems (TIS) – has recently been used to ask questions about inter-industry dynamics.

Research in the economic geography community has made substantial advances in our understanding of the impact of mature on emerging industries. However, we consider these frameworks inadequate for our purposes. The powerful notion of related variety suffers from the fact that 'relatedness' remains somewhat a 'black box' concept (Steen & Hansen, 2014) and is consequently unable to handle the multi-dimensional nature of inter-industry interaction. Research on path branching – that we understand as process studies of 'related variety' – are rather recent and still lacks a recognized framework for grasping how industry emergence (path creation) draws on resources from mature industries (old path) (Simmie, 2012a). Hence, the main recent bodies of research on inter-industry dynamics do not present us with an established framework for systematically conceptualize, analyze, and assess the extent to which new industry emergence may be supported or blocked by mature industries.

At the same time the issue of inter-industry relationships is increasingly being addressed within the field of environmental innovation studies. Here particularly advances in the Technological Innovation System (TIS) framework is enabling analysis of how distinct industries may be complementary or competing conceptualized as interaction between several TISs (Bergek et al., 2015). Although this line of research is in its infancy and several research gaps remain, the functions analysis associated with TIS studies is an established practice that ensures a degree of systematic analysis (Bergek et al., 2008).

On the basis recent advancements in TIS research we propose to conceptualize path branching as interaction between an emerging and a mature TIS. We propose to analyze their interaction through multiple 'structural overlaps' between them with particular attention to how these overlaps affect the (functions in the) emerging TIS / industry. The latter allows us to systematically analyze, and assess how and which extent an emerging industry draws on resources of mature industries. Although the paper is thus mainly conceptual we apply the proposed framework for analyzing how the offshore wind power (OWP) industry (emerging) was be supported or blocked by the presence of the offshore oil and gas (O&G) industry (mature) in Norway in the period 2005-2015. Our empirical analysis relies on both primary and secondary data sources.

Our exercise addresses the knowledge gaps identified above in several ways. First, by applying the TIS framework to study path branching helps us to explicitise the multiple dimensions of relatedness as structural overlaps which contributes to open the 'black box'. Second, the analytical stringency of the TIS framework can contribute with a new and established perspective in the embryonic path branching research tradition. Third, we build on but also add to the recent developments in TIS studies by exploring TIS-TIS interaction further and by proposing methods for mapping and assessing overlaps. Fourth, by bringing TIS out from environmental innovation studies and connect it to issues of path branching, we, in a sense, suggest a novel framework for studying industrial diversification and development. Lastly, we add to the current body of knowledge about the empirical case through our application of the TIS which enables us to systematize and connect earlier contributions in new ways (Normann, 2015; Steen & Hansen, 2014).

Section two present a deeper review of the literature and elaborates on analytical framework. Section three presents data and methods. Section four presents the case study and section five comprises the analysis of O&G and OWP in Norway. In section six we discuss results of analysis and conclude the paper.

2 Literature review: the relationship between mature and immature industries in industrial dynamics

In evolutionary thinking, industrial and economic development is understood as processes of knowledge accumulation through human learning where novelty, in retrospect, appears a smoothly emerging branch growing out of the existing knowledge stock (Boulding, 1981).

We know from technology and innovation studies that such branching (or technological diversification) does not follow random patterns. Countries' technological specialization is cumulative and tends not to leapfrog but change only incrementally. This suggests that future branching is constrained, though not determined, by past technological achievements (Cantwell & Vertova, 2004). Diversification – as structural change – is thus a path-dependent process (David, 1985). This suggests that new industries to some extent must build on and/or be compatible with existing capabilities, technology, economic conditions, infrastructure, and institutions (Dosi, 1988). In this paper we focus on the relationship between mature industries, on the one hand, and emerging and immature industries, on the other.

Inter-industry dynamics have been understood as central for industrial advance and economic development by a range of prominent thinkers associated with evolutionary economics. Hirschman (1958) argued that various forms of push and pull mechanisms between different, but related, industries give rise to 'disequilibrium' development processes that are the driving forces of industrial advance. Dahmén (1950) asserted that industrial development tends to be led by blocks of related industries (clusters) whose interaction maintained momentum.

If we consider the relationship between mature and immature industries explicitly we identify four types of interaction in the literature.

First, the classical Schumpeter example where the new industry disrupts, defeats, and replaces the old industry. Schumpeter described the hierarchy of the economic system as: "the upper strata of society are like hotels which are…always full of people, but people who are forever changing" (Reinert, 2007). Industry life cycle theorizing emerges from this line of thinking.

Second, partly related to the latter, we often see that mature industries are threatened by emerging industries and consequently try to block the emergence through different channels. This type of relationship has recently been widely studied and documented within research on sustainability transitions where incumbent energy companies act hostile towards emerging clean-tech industries endangering their business models (Markard et al., 2012).

Third, often emerging industries feed of the demand for new technologies and solutions from established and mature industries (Pol et al., 2002). Hence, new, often small and 'high-tech', firms supply productivity-enhancing and/or problem-solving innovations to large, resourceful, old, and 'low-tech' industries. Mature industries thus benefit from emerging industries. In fact, this type of relationship has largely been overlooked within innovation studies (Hirsch-Kreinsen et al., 2005) which has predominantly focused on the fast-growing high-tech industries (B. Martin, 2013).

Fourth, emerging industries use inter alia the competencies, knowledge and practices of mature industries as inputs and thereby benefit from their presence. In other words, if new industries draw on competencies that are complementary to existing competencies, they will perform better than new industries that do not (Hidalgo & Hausmann, 2009). This type of interaction has not received much attention in innovation studies but has predominantly been explored in economic geography.

This fourth type of interaction will be our starting point for asking how new industry emergence may be benefit or be blocked from the presence of mature industries.

2.1 Economic geography: Related variety, relatedness and path branching

Discontentment with the ability of traditional path dependence thinking (David, 1985) to convincingly conceptualize path renewal and new path creation (Simmie, 2012b) has, according to Asheim et al. (2013), motivated two sets of responses within economic geography. One is in the form of the concept of 'related variety', and another under different forms of path creation, extension or branching. The former tends to play down the role of institutional factors and rely on quantitative methods while the latter tends to emphasize institutions, social agency, and, in consequence, rely more on case study research.

2.1.1 Related variety

The notion of related variety conveys the message that the industrial specialization in a given region constitutes a powerful selection environment for the emergence and subsequent performance of new industries. Each territory has through economic activities over time accumulated knowledge of a certain set of production methods or technologies. If industries draw on the same technologies, they exhibit 'technological relatedness'. The core proposition thus is that technological relatedness is a significant explanatory variable – although not the only one – for emergence of new industry (Boschma & Frenken, 2011a; Neffke et al., 2011).

Moreover, firms will diversify – which they mostly do only unwillingly – in the least demanding directions; that is, where firm routines and competences are applicable with modest adaptations (Boschma & Frenken, 2011a). Hence, firms are the natural vehicles of technological relatedness.

The growing research area demonstrates that new industrial activities that are related to, or can benefit from, the existing technology bases are more likely to both emerge and be resilient over time due to knowledge spillovers (Boschma & Frenken, 2011b; Frenken et al., 2007; Neffke et al., 2011).

The latter also implies that diversity per se is not necessarily good for innovation or development. Novelty introduced into the economy ought to be different from but also related to existing technology bases in order to both add diversity to the economy and to reap benefits of knowledge spillovers.

However, the majority of studies on related variety apply quantitative methods that demand simplification of concepts to operationalize them. In this process the complexity and qualitative content of technological relatedness is often lost which implies that it remains a "black box" concept (Steen & Hansen, 2014).

Accordingly, "we still have little understanding of how regional diversification or regional branching exactly works, and through which mechanisms it is most likely to operate" (Boschma & Frenken, 2011a, p. 1), and "*there is a strong need to determine mechanisms through which the process of regional branching operates*" (Neffke et al., 2011, p. 261). In order to address these research challenges we – with this paper – follow the call by Steen and Hansen (2014) for more qualitative studies of unfolding related variety.

Furthermore, although technological relatedness is seen as the central enabling dimension of relatedness, it cannot stand alone as explanatory factor for the direction of industrial diversification. We know from evolutionary economics that the emergence of new industrial activities and path dynamics is shaped by a variety of factors including the interactions between (i) firm capabilities, (ii) structure and quality of demand, (iii) technological options, and (iv) a range of other factors such as institutions, infrastructure, and natural resource deposits (Dosi, 1988). Hence, "relatedness" is a multi-dimensional concept which may refer shared infrastructure, institutions, knowledge and/or demand between industries as the main reason for enjoying externalities. This property of industry emergence is our main motivation for proposing an innovation systems approach for understanding new aspects of related variety.

2.1.2 Path creation and branching

The path-dependency literature has, however, received wide criticism for not addressing how firms and countries can break lock-in situations. One attempt to give a more prominent and explanatory role for agency in the process of path dependency was formulated under the notion of path creation (Garud & Karnøe, 2001).

Although most emphasis was given to the role of entrepreneurs who through mindful deviation push path creation, Garud and Karnøe (2001) repeatedly point out that path creation is a collective process where entrepreneurs must engage with a wide set of distributed actors to change their context inter alia via developing new standards, institutions, knowledge, markets, and shared visions pertaining to the new path. Hence, the systemic nature of path creation was accentuated from the birth of the concept.

Although there has been limited communication between studies of related variety and path creation, recent contributions highlight the fact the path creation is path dependent, so to say. That is, how path creation processes also are embedded in a broader selection environment from which resources can be drawn. As a consequence path dependence has recently become nuanced to include different forms of path branching (Isaksen, 2015; R. Martin & Sunley, 2010).

Recently, Simmie (2012a) picked up on Garud and Karnøe's (2001) remarks on the systemic nature of path creation by reemphasizing that it essentially is a matter of collective action. Path branching thus requires the establishment of some entity resembling an associated system of innovation. Indeed, Sæther et al. (2011, p. 379) argue that historical studies of innovation system formation can enhance our understanding of path creation. In fact, the authors implicitly suggest that each path is associated with a (sectoral or technological) system of innovation affecting the intensity, direction and mode of change. If we take this perspective one step further we come to see a path, ex post, as an innovation system propelling through time and space, and, ex ante, path creation as a challenge of innovation system building.

Considering the hitherto accumulated body of knowledge on path creation and branching there is, according to Simmie (2012b, p. 754), still a need for better explanations of how new technological and industrial paths created, and how they relate to both historical conditions and current circumstances.

We will argue that the TIS framework – which was developed to grasp the complexity of new industry emergence – with some modifications can contribute to our understanding of the systemic processes involved in path creation and branching.

2.2 Environmental innovation studies and technological innovation systems

2.2.1 Technological Innovation Systems: contents and trends

Technological innovation system (TIS) has been under continuous conceptual development in innovation systems literature. The TIS framework focuses on emergence and growth of new industry and/or knowledge fields (Carlsson & Stankiewicz, 1991). A TIS is defined as a set of the actors, networks and institutions engaged in developing, diffusing and utilizing new products (goods and services) and processes related to a certain technological field or industry (Bergek et al., 2008). The perspective has been found very useful for analysing emergence and growth of clean-tech industries in the context of heightened concerns about climate change (Jacobsson & Bergek, 2011). Through numerous applied clean-tech studies the TIS was reconceptualized to encompass a 'functions approach' whose proponents criticize previous IS research for being largely limited to descriptive analysis of system structures while ignoring system dynamics (Bergek et al., 2008; Hekkert et al., 2007).

Bergek et al. (2008) propose to supplement such structural analysis with a focus on generic key processes, activities or functions (functions, hence forward). The notion of functions emerged as a need for an analytical meso level between components of an IS and its performance. The idea is that IS performance cannot be reduced to the existence or absence of system components. Instead, the actions of actors operating within a given structure, and how these affect innovation, must be made explicit in the analysis. Based on an extensive literature review, Bergek et al. (2008) present a well-founded but necessarily open-ended set of functions that are crucial for IS performance: knowledge development and diffusion (F1), influence on the direction of search (F2), entrepreneurial experimentation (F3), market formation (F4), legitimation (F5), resource mobilization (F6), and development of positive externalities (F7). The functions emerge from interaction between TIS components (actors, networks, institutions, and technology) of a system under influence of external forces. The overall hypothesis of this approach is that all functions must be 'strong' for successful industry emergence. In consequence, assessment of functions is considered a tool for identifying strengths and weaknesses of a given TIS at a moment in time to inform policy makers.

However, a drawback of the framework is that it has focused very much on single technologies which risks overlooking important interactions with other relevant technologies and sectors (Coenen & Díaz López, 2010; Jacobsson & Bergek, 2011; Markard & Truffer, 2008).

This weakness has been exposed but also explored in several studies of inter alia international couplings (Binz et al., 2014), interaction between several technologies (Andersen, 2014; Sandén & Hillman, 2011), and importance of wider policy setting (Markard et al., 2015).

On the basis of these and other studies leading TIS scholars have recently outlined a preliminary research program for the advancement of grasping the importance of four different types of context (including other TIS, sectors, geographical context, and political context) for a the dynamics of a focal TIS (Bergek et al., 2015). Here we focus on the interaction between two TISs. Although research along the lines discussed is only beginning, we argue that these recent developments in TIS research enable us to apply the framework to the study of different forms of interaction between technological trajectories or paths much in the same mold as path branching research.

2.2.2 Analytical framework: Interacting Technological Innovation Systems

Our starting point for thinking about overlaps between TISs is the distinction between, on the one hand, technological systems and, on the other hand, technological support systems (De Liso & Metcalfe, 1996) or technological innovation systems (Sandén & Hillman, 2011). The notion of technological systems refer to the perspective that all technologies can be understood as recursive systems consisting of subsystems (alternatively components and modules) (Arthur, 2009; Arthur et al., 1997). Recursiveness implies that technological systems can be delimited in numerous ways across levels of aggregation (Sandén & Hillman, 2011). In this perspective both an individual industry (regardless of maturity) and a broader value chain can be considered technological systems. A technological support system or TIS refer to the 'societal' actors, networks and institutions that support, hinder, or directs development of the technological system. These elements are the main objects of policy. This implies that the TIS concept is applicable for analysis of a variety of industry and system delimitations including both mature and immature industries.

Structural overlaps or couplings are defined as components shared by TISs. Shared components are the basis for TIS-TIS interaction. Components include actors, networks[1], institutions[2], technology[3] (Bergek et al., 2008; Jacobsson & Bergek, 2011) and physical infrastructure.[4] These five types of components constitute dimensions of overlaps between TISs. In fact, we consider them to be dimensions of relatedness between (the old and the new) technological paths which enables us to open and explore the black box of relatedness.

Some degree of overlap is to be expected in most TISs due to the simple fact that most firms operate in multiple TISs. One extreme case would be (general-purpose) ICT companies that are often active and influential in many other industries beyond the technological field of ICT. Also, often institutional developments (e.g. in the form of R&D policies or trade regulation) often impact a range of industries.

Although numerous forms of TIS-TIS interaction have been discussed (Sandén & Hillman, 2011) we limit ourselves to the two most basic forms of interaction: competition (negative

[1] In the TIS tradition it is custom to broadly distinguish between two types of networks. (1) learning networks including user-supplier and industry-academia relationships, and (2) "political" networks (or advocacy coalitions) that seek to change institutions in support of the TIS (Jacobsson & Bergek, 2011).

[2] Institutions are sets of common habits, routines, established practices, rules, or laws that regulate the relationships and interactions between individuals and groups. Organizations are actors, whereas institutions are conceived as a structure that influences actors.

[3] Technology is here understood as relevant knowledge bases (stock) in society including tacit, codified, embodied, and disembodied knowledge.

[4] Although physical infrastructure is not always considered in single-TIS analysis recent research has highlighted its importance in TIS-TIS interactions (Andersen, 2014) and in path branching (Fornahl et al., 2012).

interaction – i.e. TISs compete for resources) and complementarity (positive interaction – i.e. TISs benefit each other) (Wirth & Markard, 2011).

The notion of 'interaction' suggests that overlaps affect all TISs involved. In our case we limit ourselves to considering how a focal TIS is affected by its structural overlaps with a mature TIS in its context. We assess impact on focal TIS by analyzing how different structural overlaps affect the functions pertaining to the focal TIS within a short period of time. This delimitation is motivated by our case. It is more likely that a mature TIS will affect an emerging TIS than vice versa. These considerations form our analytical framework which is portrayed in Figure 1. The framework allows us to systematically assess how a focal TIS is affected by its overlaps with a context TIS.

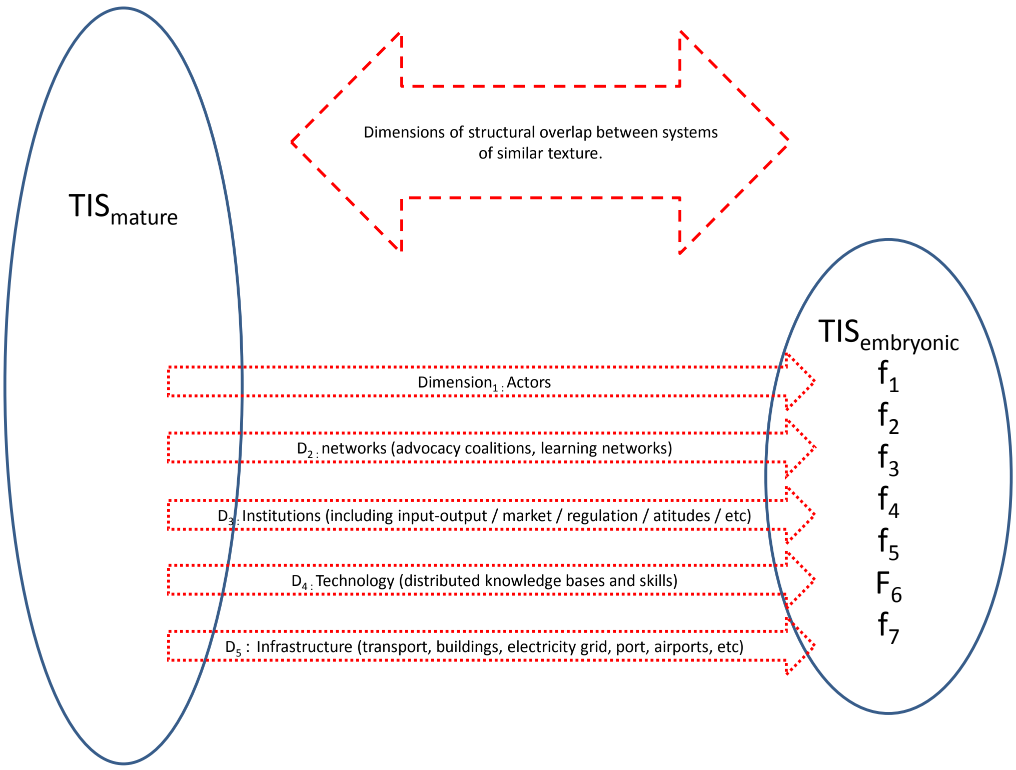

Figure 1. Analytical framework[5]

It is not our intention to give a full description or analysis of the focal TIS (Norwegian offshore wind power). Hence, we do not explicitly analyze the impact of actors and other components which are not shared by both of the industries, see Figure 2.

[5] If we analyzed longer term interaction the arrows would be 2-way.

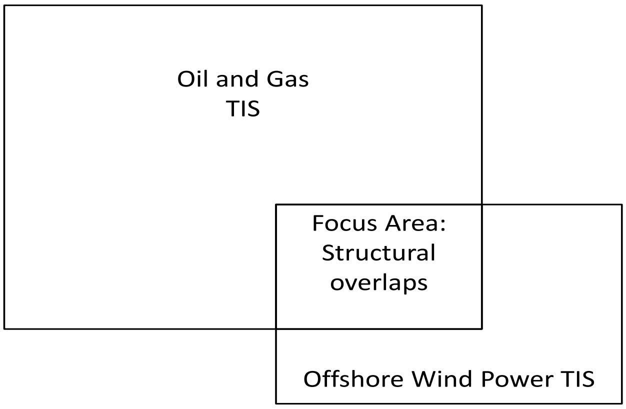

Figure 2. Structural overlap between established and emerging industry.

This analytical framework can potentially contribute to the discussion of path branching and related variety in Economic geography in two ways. First, by denoting types of overlaps as dimensions of relatedness, the framework can be used to open and explore in more nuances the notion of relatedness in a systematic way. Second, although the functions analysis is far from perfect it constitutes an established and systematic framework for evaluating enabling and blocking forces for emergence of new industry. This type of analysis can complement the upcoming path branching research.

Moreover, by being one of the first attempts to explore TIS-TIS interaction our framework and subsequent analysis can possibly contribute to TIS research on, at least, four accounts.

First, our in depth analysis of structural overlaps between two TIS hold lessons for some preliminary hypotheses set out by Bergek et al. (2015) including how it can be difficult to establish strong networks and alliances when the actors of a TIS are active in more TISs, and how actors moving into a new TIS can suffer from the institutional rigidity of the old TIS e.g. in the form of incompatible firm routines, practices and business models.

Second, our analysis brings methodological insights about how to identify and map structural overlaps, and how these can be linked to functions analysis of the focal TIS.

Third, most TIS research has focused on emerging industries and less is therefore known about the dynamics of mature TIS. Our analysis is the first, we know of, that consider the relationships between mature and emerging TISs.[6]

Fourth, we propose to bring the recent advances in TIS research out from the environmental innovation area, where it has incubated, and connect it to more general discussions of industrial path renewal and diversification. In doing so, we reposition the TIS framework as applicable for studying inter-industry dynamics in various ways and thus broadens its scope.

3 Methods and data

[6] We note that the functions are developed particularly for the study of emerging industries and are, most likely, not meaningful for analysing dynamics of mature industries.

We use a single case study where both our focal TIS and the established TIS are well described in the literature. In addition, their interaction has also been subject of research (Hansen & Steen, 2011, 2015; Normann, 2015; Steen & Hansen, 2014; Steen & Karlsen, 2014) wherefore we have access to extensive secondary empirical material. Although the cases have been analyzed before, it is novel to apply the extended TIS structural overlap framework to them. The focus is on years 2005-2015 when the TIS of OWP in Norway started to take shape. We delineate our view in O&G industry to upstream operations, i.e activities related to oil and gas extraction in offshore conditions, and do not include e.g. refinery and distribution activities. We identified various overlap indicators, such as actors active in both O&G and OW industries, O&G companies involved in OWP specific networks, institutions, technologies and infrastructure relevant or used in both industries, and reports of knowledge diffusion from O&G to OW.

The database on OWP companies consisted of a survey which has recently been carried out in TIK. The sample of companies in the survey was drawn from industry reports, industry organization memberships and desk research, and included companies that had, or had ambitions to deliver, products and services to OWP industry. This survey (response rate 109/183: 60%) collected information e.g. about the primary market of company, supply chain position, full-time employees dedicated to OWP, and prior industry experiences. Additionally to the survey, we collected publicly available data from public national registries (Brønnøysundregistrene) by using proff.no website. We also used 4C Offshore Wind Farms Database, which reports all stakeholders involved in OWP developments in the world, and company websites. We concluded with 169 OWP companies[7] in total.

The database on O&G has been collected in accordance to a research project on Norwegian petroleum-related supplier companies (SIVAC). It has been collected by using reports about supplier companies, industry organizations and publicly available company data. This database included 621 firms at the time of analysis. However, the total number of Norwegian oil and gas related supplier industry has been estimated to include approximately 1300 companies.[8] From the 169 OWP companies we identified the ones which are active also in O&G, and concluded with 99 companies in total (see Figure 3)[9].

[7] This number should be treated as an estimate of Norwegian OWP industry.

[8] Several estimates of number of companies have been presented, ranging between ~1300-2700 companies (Rystad_Energy, 2013, p. 95). We chose to use the most conservative estimate of ~1300 companies.

[9] Our methodology identifies only the companies which have or have had activities in both OWP and O&G under the same organization.

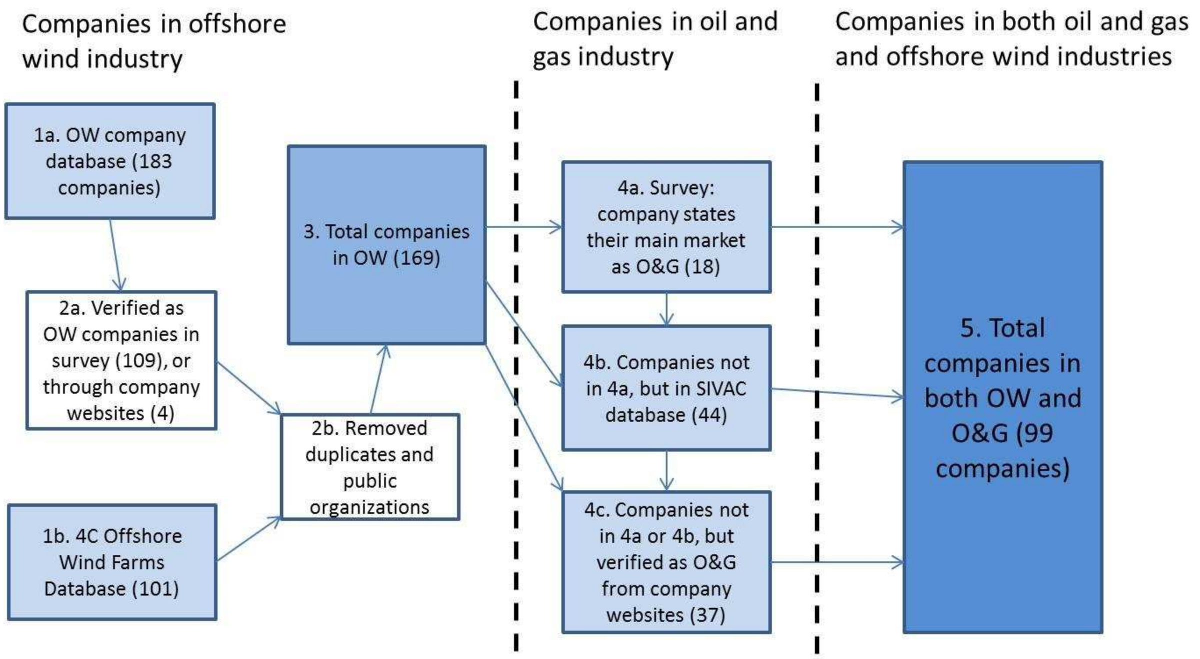

Figure 3. Methodology for determining actor overlaps between OWP and O&G industries.

By using the Espacenet database of European Patent Office, we identified OWP specific patents owned by Norwegian companies. We used Cooperative Patent Classification (CPC), which enables to search patents relevant for wind energy generation. By using search words related to offshore conditions, we identified 48 patents. The patents and search words are presented in Table 1.

Table 1. The used CPC patent categories and search words

Code	Patent category	Search words
Y02E10/721	Blades or rotors	"offshore OR floating OR buoyant OR water OR marine OR sea OR vessel"
Y02E10/722	Components or gearbox	
Y02E10/723	Control of turbines	
Y02E10/725	Generator or configuration	
Y02E10/726	Nacelles	
Y02E10/763	Power conversion electric or electronic aspects 1) for grid-connected applications	Country: [NO]
Y02E10/766	2) concerning power management inside the plant	
Y02E 10/727	Offshore towers	Country: [NO]

By searching through the membership lists of six Norwegian formal networks related to OWP (NORCOWE, NOWITECH, Arena NOW, Windcluster Norway, NORWEA, INTPOW), we investigated how many of the industrial partners are active also in O&G industry. Our assumption is that overlap companies present in OWP networks are also integrated in various types of formal and informal networks in O&G industry, thus acting as bridges between the industry networks.

By drawing on our data sources and results in O&G and OWP overlaps, we qualitatively interpreted implications of these interactions to the TIS functions of OWP.

4 Case description

4.1 Mature industry – Oil and Gas industry

The Norwegian petroleum innovation system (NPIS) in offshore oil and gas technologies started to take shape during the 1970s. Using their existing competences, actors from engineering industries, shipping and aluminum and hydro power sectors in Norway started to activate in the new industry. The newly established national oil and gas institutions Statoil (the national oil company), the Norwegian Petroleum Directorate and the Ministry of Oil and Energy facilitated conditions for international oil companies, which included e.g. involvement of Norwegian suppliers and competence transfer to Norwegian actors (Engen, 2009; Saether et al., 2011). These framework conditions of the Norwegian government institutions affected e.g. the technology choices for the first oil rigs in the Norwegian continental shelf. The NPIS has evolved through the interplay of international oil companies and their Norwegian suppliers, R&D institutes and universities (Engen, 2009; Saether et al., 2011).

By 2000 the oil and gas industry was in an unprecedented boom due to the rise of oil price (Engen, 2009). However, the recent years have witnessed a dramatic drop from $110/barrel in July 2014 to $45/barrel in November 2015. Such fluctuations are characteristic for the oil price, and while periods with high oil prices might result in boom periods, the today's low price is causing a downturn in the Norwegian O&G industry (Figure 4).

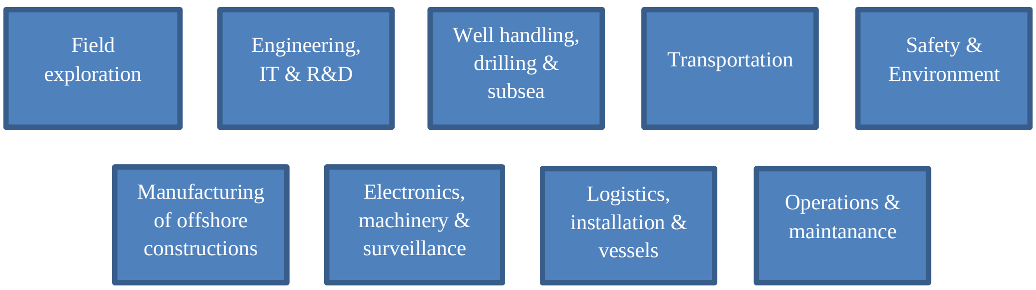

Figure 4. Supply chain for offshore O&G production

4.2 Focal TIS – offshore wind industry

Norway, despite having vast potential for harvesting OWP, does not have installed capacity, excluding a single demonstration project of Statoil. This is largely due to the energy system of the country, which receives 99% of its electricity from carbon neutral hydroelectric power. Therefore, Norway has not faced the need to decarbonize its energy production system, and therefore has not been forced to make investments in other sources of renewable energy (Hanson et al., 2011). Due to e.g. unfavorable political conditions, by 2014 only the one demonstration project has been realized and connected to the electricity grid (Normann, 2015).

Fairly large number of 150-200 companies have been estimated to be involved in the OWP TIS in Norway (Steen & Hansen, 2014). Many of these companies are focused on offshore activities, and offer e.g. engineering and installation services, but include actors in all fields of the OWP supply chain presented in Figure 5 (Normann & Hanson, 2015). Knowledge production in OWP has been supported by a handful of research organizations such as SINTEF, which has collaborated with companies in R&D activities. Other important research actors have been the two network-like Centres for Environment-friendly Energy Research (FMEs), NORCOWE and NOWITECH. From governance side, one relevant public institutions is the Norwegian Water Resources and Energy Directorate (NVE), which is responsible for the management of the country's water resources and a subsidiary directorate related to the Ministry of Petroleum and Energy (MPE).

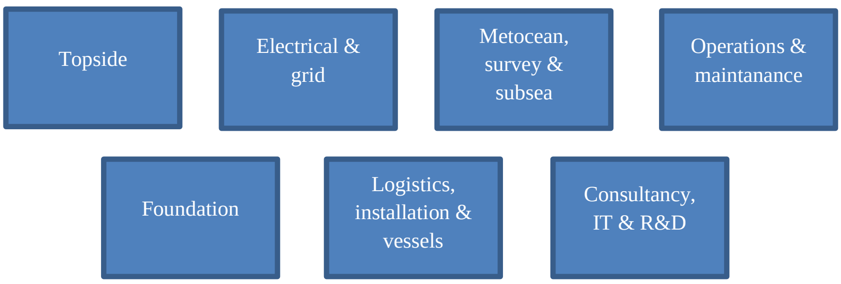

Figure 5. Supply chain of OWP production

5 Analysis: structural overlaps and implications

5.1 Structural overlaps

In the first part of this chapter we analyze structural overlaps between the O&G and OWP industries in the five dimensions of actors, networks, institutions, knowledge base and technology, and infrastructure.

5.1.1 Actors

Basing on our data on the two industries, we can see that the majority of the companies in the Norwegian OWP industry (~62%) are directly linked to O&G activities, while these 99 companies form only a minor part of the total amount of companies in O&G industry (see Figure 6). Logistics, installation and vessels formed the largest activity (32%) in the supply chain of OWP (see Figure 7).

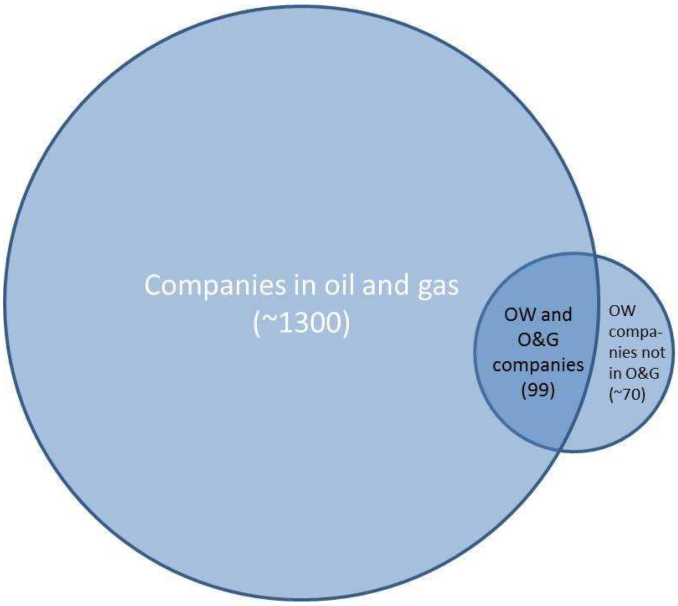

Figure 6. The company overlap between O&G and OWP in scale.

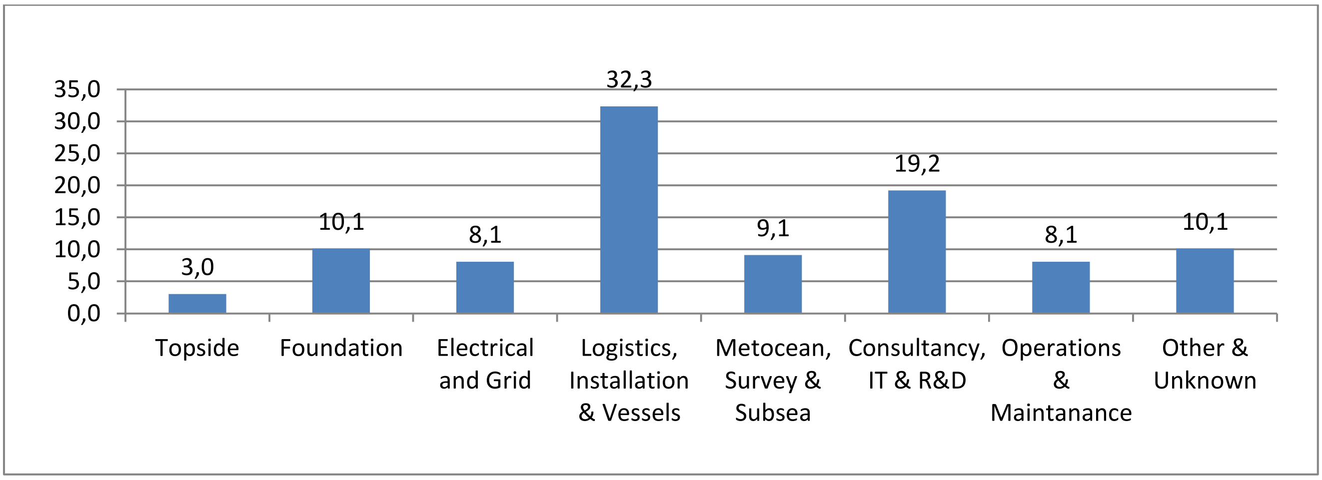

Figure 7. The overlap companies on the supply chain of OWP (percentages, n= 99).

These results support the assumption that the activities of overlap companies are mostly related to offshore conditions. Many overlap companies were in the business of designing, installing or transporting offshore constructions which are relatively similar operations in both O&G and OWP industries. In contrast, the supply chain position with least commonalities with offshore competences, namely the topside technologies (e.g. blades, generators etc.), was by far the smallest segment with 3% of overlap companies.

In terms of revenue, around 39% of the overlap companies are micro or small enterprises with yearly revenue of less than 100 Million Norwegian Krones (NOK), while 29% are large enterprises with more than 500 Million NOK turnover. This is noteworthy, as it seems that the overlap companies are larger than the rest of the petroleum-related supplier companies in Norway (Table 2). Parallel with the size, the overlap companies are also slightly older with median founding year of 1997 (n=97), compared to the median year of 2000 of O&G

companies in general (SIVAC database, n=609). The median year for OW companies in Norway to become activated in this industry was 2009 (n=101).

Table 1. Company size in terms of revenue in 2013: OWP and O&G overlap companies in comparison to O&G companies.

	Micro, < 20 M NOK	Small, 50-100M NOK	Medium, 100-500M NOK	Large, > 500 M NOK
OW and O&G overlap companies, n=91	13,2%	25,3%	33,0%	28,6%
O&G supplier companies, SIVAC database, n= 460	18,5%	28,9%	33,5%	19,1%

The amount of fulltime employees dedicated to OWP in overlap companies is generally very small. As can be seen in Table 3, 60% of the companies have less than 10% of their employees working specifically in OWP. This would suggest that the majority of overlap companies have low engagement in OWP, and this market does not seem to be of primary importance to most of them.

Table 2. Company engagement in OW: share of full time employees dedicated to OW from total number of employees

	Minimal, <1%	Small, 1-10%	Medium, 10-50%	Large, >50%
OW and O&G overlap companies, n=60	25%	35%	28,3%	11,7%

5.1.2 Networks

We found out that the O&G related overlap companies were in the minority of the industrial members in all of the six identified OWP networks (presented in Data and Methods chapter). This is noteworthy because, as previously presented, the majority of companies in OWP industry are also active in O&G, but non-O&G companies are the majority in all of the formal networks related to OWP. This seems to suggest that many overlap companies do not see OWP specific formal networks relevant for their activities, which is in line with the notion of low engagement in OWP. Also Steen and Hansen (2014, p. 2042) note that diversified O&G companies rather collaborate in more bilateral manner with other firms with complementary assets.

Normann (2015, p. 187) has argued that establishing two OWP focused FMEs (NORCOWE and NOWITECH) simultaneously created “unhealthy competition over researchers, funding and industrial partners”. Meanwhile, Normann (2015) further reports, the emerging TIS in Norway was suffering from the lack of funding for demonstration projects. Two noteworthy proposals for demonstration projects emerged around the same time, Demo Rogaland and Demo2020. This caused another competitive situation which damaged the whole process of realizing demonstration projects, and the projects failed to secure public funding. This was due to the lack of collective action and “weak networks” among OWP actors which harmed the drive for reaching political consensus on concrete public financial support for OWP demonstration projects (Normann, 2015, p. 189).

The status of O&G had high relevance for the OWP advocacy networks of the country in 2009 which saw a rapid fall in oil price in the aftermath of the financial crisis of 2008 (Normann, 2015). However, the OWP industry was not able to turn the downturn of O&G into concrete actions in OWP investments. When the emergence of domestic market in OWP seemed unlikely, major energy companies, including O&G giants like Statoil, opted to invest in OWP projects abroad. According to Normann (2015), Statoil consequently showed little interest in working together with other Norwegian companies in the these projects outside Norway. Additionally, when new oil discoveries were announced in 2011, more optimism towards O&G industry reoccurred in Norway, which reduced the perceived urgency for the development of alternative industries such as OWP (Normann, 2015).

5.1.3 Institutions

While the growth and success of the Norwegian O&G supplier industry is credited to the interventionist policies of the Norwegian government from the 1970s onwards (Engen, 2009), the national institutions have not yet been as eager to create a domestic OWP market. The governance of both O&G and OWP resources are subjected to the same institution of Ministry of Petroleum and Energy (MPE). As Normann (2015) reports, the appointments and political agendas of different Ministers of Oil and Energy have played an important role. While some Ministers have been more positive about developing national competences and market in renewable energy production, some others have been more focused on the existing industry of O&G. Such discontinuities in the approach of a central national institution can be seen to have created uncertainty in the OWP industry.

However, in terms of more informal institutions, it has been argued that OWP can learn from the experiences of O&G industry in established practices and norms related to working in offshore conditions, which often are subjected to difficult weather conditions. Together with competences related to managing large offshore projects, norms and experiences from O&G sector can be useful in creating know-how in the emerging OWP industry (Steen & Hansen, 2014). In relation to similar types of offshore competences, Edwards (2011) has suggested that OWP could benefit from the learnings of O&G industry e.g. in terms of health and safety rules and regulations. O&G companies in the North Sea have improved safety standards in the offshore activities in the process of several decades of experience riddled with accidents.

5.1.4 Knowledge base and technology

Our analysis on patents shows that 12 of the 48 patents directly related to OWP in Norway are owned by an overlap company, and several more are owned by companies which had direct or indirect links with the O&G industry. At least half of the patents were tied to O&G industry either by ownership, or by clearly drawing on well-known technological concepts from O&G. Illustratively, many of the patents are related to floating wind power technology, which has been pursued by e.g. Statoil, and OWP foundation techniques similar to ‘condeep’ concept pioneered by the Norwegian O&G industry in the 1970s.

Foundations, i.e. the construction which attaches the OWP installation to sea bottom, has been an area of technology where techniques from O&G have been transferred to OWP. Diversifying companies have perceived that OWP offers them opportunities to use their existing knowledge base (Hansen & Steen, 2015). By moving into OWP from O&G, such companies have brought their knowledge base with them which enables these firms to develop OWP specialized products faster and induce knowledge development in the TIS.

An example of technology transfer is the gravity-based foundation technique of Seatower company, a specialized OWP firm, which reuses the above-mentioned condeep concept (hollow concrete pile attached to the sea bottom), which became famous in the NCS during the early decades of Norwegian O&G extraction.

Activities such as offshore structural design, transportation and installation are fields where the OWP has benefited from the expertise of the O&G sector. As seen in Figure 8, many Norwegian companies in different parts of the OWP supply chain draw from experiences in the O&G industry, for instance, by being previously employed within the O&G industry. However, some adaptation is needed to convert the former O&G experience to meet the specific requirements of the OWP. As can be seen in Figure 9, the survey results show that around 68% of the overlap companies claimed that their experiences from O&G were transferrable to OWP after some changes, while 15% reported major changes, and 17% no changes.

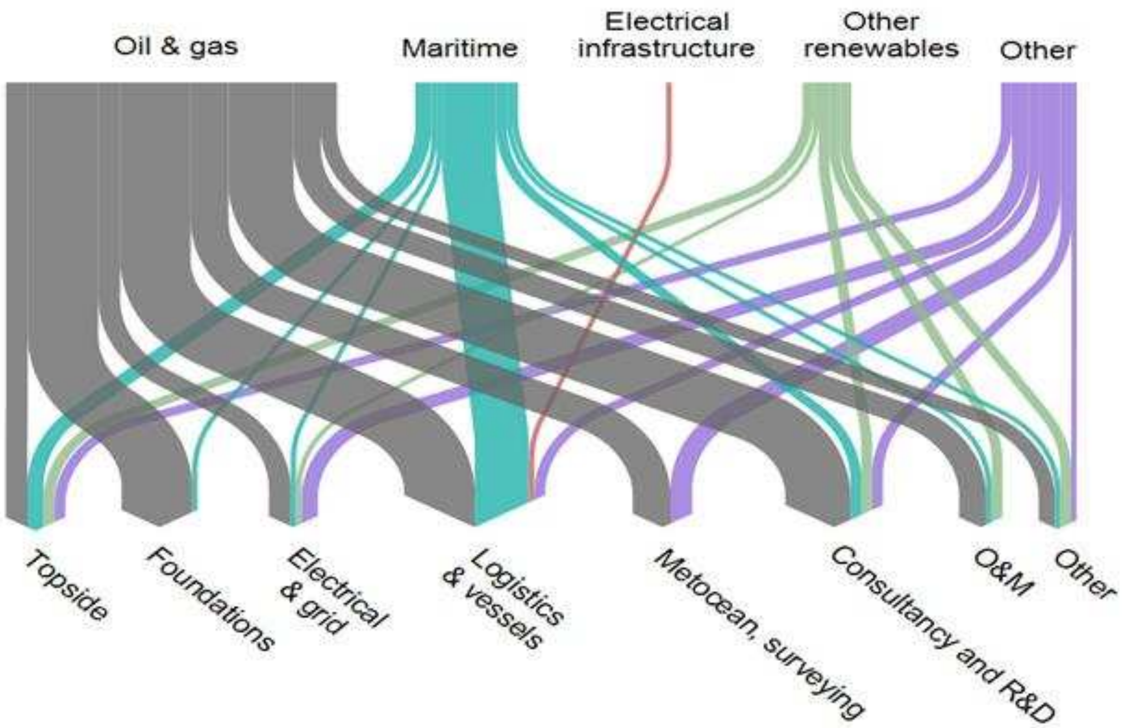

Figure 8. The industries from where the companies in the supply chain of OWP draw their experiences. The thickness of the line represents the number of companies (Normann & Hanson, 2015).

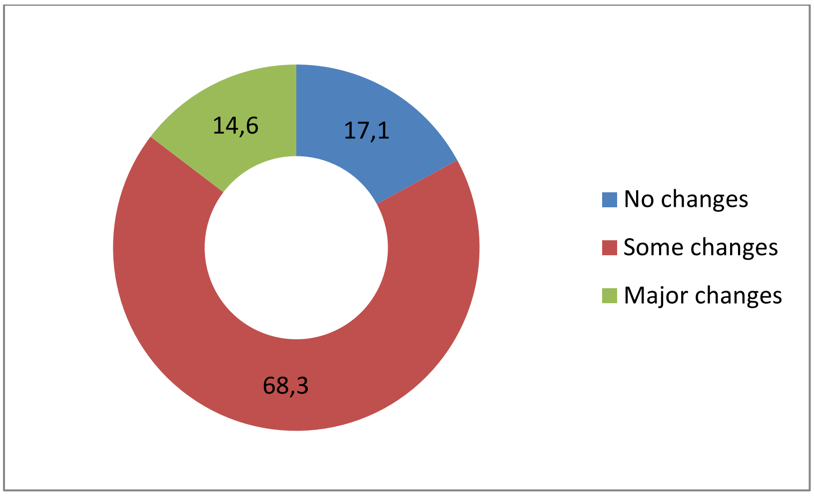

Figure 9. The extent where the activities in OWP base on experiences in O&G (percentages, n=41)

5.1.5 Infrastructure

Both O&G and OWP need certain infrastructure required in marine operations, such as ports, yards and vessels. For instance Steen and Karlsen (2014) point out that the existing infrastructure related to O&G has been used as an argument for attracting investments from OWP supplier companies. For instance, they report that the existence of yard infrastructure played a part in the decision of GE to invest in a branch plant in Verdal, in Mid-Norway.

The need to electrify offshore O&G rigs has acted as a niche market for developing floating OWP technologies for deep water conditions. According to Statistics Norway (2015), in 2013 the emissions from oil and gas extraction summed up to 26% of the total greenhouse gas emissions of Norway due to gas burning to produce power for the platforms. This has led oil companies such as Statoil to seek alternative ways to electrify oil rigs, which has given boost to floating OWP projects like Hywind (Hansen & Steen, 2015). However, due to unclear regulatory framework, it was not possible to connect Hywind to petroleum installations, and the niche opportunity was lost (Normann, 2015, p. 185).

5.2 Impact on focal TIS - functions

5.2.1 Knowledge development and diffusion

The large majority of the overlap companies are related to offshore operations which enables them to draw on their existing competences in O&G and diffuse this knowledge to the OWP industry. This can take place at the level of technology, but also institutions, such as norms and regulations related to safety and offshore operations. However this complementarity is reduced by different standardizations in the two industries, and the higher importance of costs in the OWP industry. As seen, most O&G related companies have to adapt their products to the OWP market, which leads to OWP-specific knowledge development. Therefore the O&G knowledge does not only merely transfer to the emerging industry, but rather serves as a source material for solving new needs stemming from OWP (Steen & Hansen, 2014). These companies are able to develop OWP products faster, which supports the dynamics of knowledge development in OWP. Also, by adjusting proven technological concepts from O&G, such as the condeep foundation, the established industry can supply the emerging industry with technologies which have novelty in the new market, but have been proven in the old market.

However, only some of the diversified O&G companies were present in formal networks related to OWP. This would indicate that the overlap companies do not seem to be taking part in learning processes through industry-wide networks. The apparent low engagement of many overlap companies can therefore reduce their potential positive impact on knowledge development and diffusion.

5.2.2 Direction of search

Complementarities between the technologies used in OWP and O&G industries and the opportunities to make use of the existing competences and knowledge base of the companies have acted as motivations for firms to join the OWP TIS (Hansen & Steen, 2015). This has attracted several companies from the O&G to join the OWP as it offers new market opportunities. However, the engagement of many companies is low, which leaves it unclear how big of an impact does these companies have on the direction of search function of the OWP TIS. Additionally, Hansen and Steen (2011) have suggested that the high cost and profit levels in O&G might hinder the willingness to join the less profitable OWP industry. Also, as the domestic market for OWP has not developed in Norway, the industry runs the risk of stagnating the number of entering companies, as it can be challenging to enter foreign markets without references from home market.

5.2.3 Entrepreneurial exploration

As was seen, the companies diversifying from O&G to OWP adapt their products to the new market. Also several O&G related companies possess OWP patents, and specialized OWP companies have used concepts from O&G as inspiration in exploring novel technologies. However, these activities are fairly small-scaled, and for instance the total number of patents in OWP in Norway is minimal in comparison to some other North Sea countries such as Denmark and Germany. This would indicate that while entrepreneurial exploration function has to some extent benefited from the O&G legacy of Norway, these competences seem not to have translated into large-scale technological exploration.

5.2.4 Resource mobilization

The overlap companies are exceptionally large and established in comparison to average O&G companies. This could suggest that the overlap companies would be able to mobilize financial and human resources in the emerging TIS. For example, the national O&G giant Statoil has been in the forefront of developing and investing on floating OWP installations designed for deep water conditions. Additionally, the human resources from O&G act as a major source of relevant competences for OWP, and many companies in OWP claim to base their experiences in the O&G field. Another complementary factor has been the available physical infrastructure, such as harbors and yards developed for the purposes of O&G, which have been used for e.g. manufacturing and transport of OWP products and services. However, during in a potential coinciding boom period in O&G and OWP, shared infrastructure could become a potential bottleneck for the development of OWP, as major suppliers can prioritize the O&G market in hopes of higher profits.

On the other hand, the national institutions have not been willing to invest on demonstration projects which would be necessary for creating important learning processes in the OWP TIS. Normann (2015, p. 189) has suggested this to be caused by poor coordination and collaboration, or "weak networks", within the OWP TIS.

5.2.5 Legitimation

Due to the sheer size of the companies, the involvement of powerful O&G actors such as Statoil have brought legitimacy to the OWP TIS, and especially for floating OWP technologies. Additionally, the large OW park projects of Statoil in UK have been reported to create momentum and credibility to the whole OWP industry in Norway, and increased the expectations of the Norwegian suppliers towards the OWP market (Hansen & Steen, 2015). O&G also acts as a legitimation source for offshore technologies and competences implemented in OWP. Companies from O&G can make an argument for their capabilities to operate in offshore conditions even if lacking experience in OWP, which can increase the credibility of wind farm developments in the eyes of investors.

5.2.6 Market formation

Powering offshore O&G platforms posed some early niche market opportunities in OWP, which partly induced Statoil to invest in R&D in OWP. These plans did not Despite the presence of large and influential O&G companies, the actors of Norwegian OWP TIS have not been able to create enough public pressure to establish a viable home market in OWP. Instead of committing to pursue a domestic market, major companies like Statoil have eventually made investments abroad. Also the governmental institutions have had discontinuous commitment to OWP development which has been harmful for the market formation (Normann, 2015).

5.2.7 Positive externalities

The strong involvement of O&G industry can be seen to have both positive and negative implications to the overall dynamics between functions of the OWP TIS. On the one hand the close connection between the two industries can be seen to have enabled the OWP TIS to get a jump-start from the existing structures and resources e.g. in terms of actors and technologies related to offshore operations. However, this close connection has caused the OWP to be subject to notoriously volatile development taking place in the O&G sector, e.g. in terms of investment decisions related to oil price. Many overlap companies have considered OWP as potential market to fill the "gaps" between the assignments from the O&G market (Hansen & Steen, 2015) which leaves the commitment of such overlap companies to OWP sporadic.

6 Discussion and Conclusions

We have aimed to contribute to the discussion in the academic fields of economic geography and environmental innovation regarding the various types of ways how emerging industries are shaped by their connection to older, more established industries. Our paper has attempted to combine these discussions and, has suggested an extended TIS framework which enables to understand and analyze the implications of structural overlaps between an established industry and an emerging TIS. We have also explored some potential methodological avenues to investigate structural overlaps and their implications.

As 'relatedness' in economic geography suggests, new industries draw on industries with similar technologies (Boschma & Frenken, 2011a; Neffke et al., 2011). This has clearly been the case in Norway in the emergence of OWP industry. Firms with ties to O&G industry have diversified to the novel industry by using their existing competences with some adaptations (Boschma & Frenken, 2011a). Technological developments in the OWP have benefited from knowledge spillovers from O&G through overlaps in actor or knowledge base dimensions (Fornahl et al., 2012; Neffke et al., 2011). Looked from another perspective, such significant structural overlap between O&G and OWP can cause "path dependent path creation". The novel OWP TIS does not only share some of the actors and technologies with the O&G industry, but is linked with this established industry in all identified dimensions of structure. While the emerging industry benefits from the offshore competences stemming from the O&G industry, these thorough structural overlaps can also have harmful implications, such as making the OWP industry subject to the volatility and fluctuations of the O&G market (Normann, 2015). Hence, while the mindful deviation (Garud & Karnøe, 2001) of actors from established industries can be in key role in equipping the novel industry with resources, this flow of knowledge does not ensure the success of an emerging industry.

Our paper has further contributed to the discussion regarding TIS contexts (Bergek et al., 2015). By analyzing the implications of significant structural overlaps with an established TIS, we have illustrated the different dimensions where novel industries can interact with existing ones. Such discussion of applying the TIS framework in the examination of established industries, such as offshore O&G industry in our case study, is fairly novel approach in TIS studies, and requires further elaboration. Our paper is some of the first steps in studying the relationships between mature and emerging TISs, and further work is needed. The role of overlap characteristics remains an issue which would call for future research. For instance, in our case study the overlaps between industries are characterized by certain types of companies, namely large companies with relatively small engagement in the new TIS, and whose experiences from their original industry can be transferred to the novel industry with only some changes. Whether this is typical also in other mature-emerging TIS interactions, and what are the implications of such types of overlaps for the emerging TIS, stand out as possible further research avenues. Also more specific analyses regarding the characteristics of technology overlaps is needed, for instance regarding the types of knowledge bases which are directly transferred from established industries or used for developing new products in a novel TIS.

In our case study, the overlap companies, many of them large multinational firms, are not highly committed to the emerging TIS of OWP. This situation raises questions whether such companies are truly interested in OWP as a viable future market, or merely branching out to this field for purposes of public image and attracting talent (cf. Hansen & Steen 2015). The potential legitimacy benefits from the involvement of big players can therefore turn against itself. The field might appear to be controlled by large companies, and the TIS might seem to be in less need of public interventions e.g. in terms of funding, even though in reality the commitment of large players can remain very superficial.

In sum, our analysis shows that structural overlaps with established industries can have significant implications for TISs (Bergek et al., 2015). Understanding and further exploring such dynamics is relevant for both academics and policymakers in countries like Norway, where plenty of expectations are put into new industries and sources of economic activities which would make use of existing competences and industrial characteristics in the country.

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